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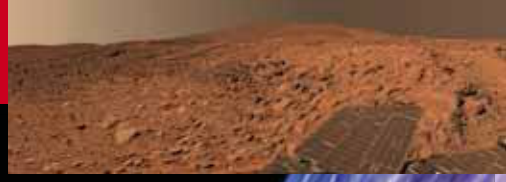

August 2005
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COSMOLOGY

## Seeing the dawn of time

How inflation theory rescues the Big Bang p. 34

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A fraction of a second after the Big Bang, the universe hyper-inflated from a subatomic particle to the size of a softball. PAGE 34

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# "I have a lot to say about my LXD75. This photo says most of it."

Pinwheel Galaxy (M101) by George Moromisato. Meade LXD75 8" Schmidt-Newtonian @ f/4. Meade DSI (480 frames X 1 minute each)

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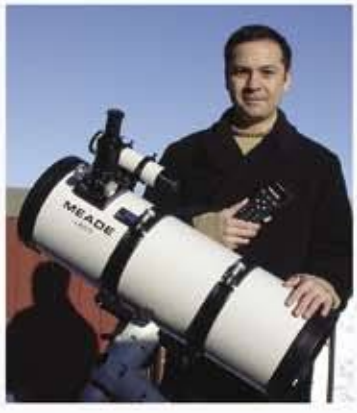


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Sunflower Galaxy (M63) by Steve Hamilton. Meade LX90 8" Schmidt-Cassegrain @ f/3.3. Meade DSIPro (L=10X4 min., R=6X4 min, G=6X4 min, B=2X4 min). Processed with Drizzle.

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**ON THE COVER**

Immediately after the Big Bang, every last morsel of our universe existed in a sphere a fraction of the size of a subatomic particle. That's when "inflation" kicked in, driving a brief period of hyper-expansion that created the cosmos we see. Now, scientists ponder "eternal inflation," in which our universe is one of infinitely many.


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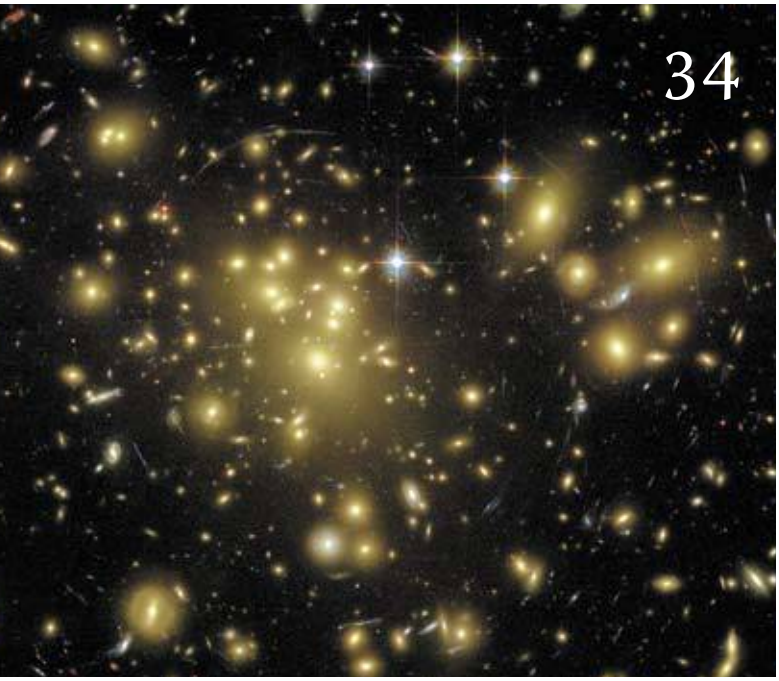
Observing, telescopes, origin and fate of the cosmos

VOL. 33, NO. 8


## august 2005

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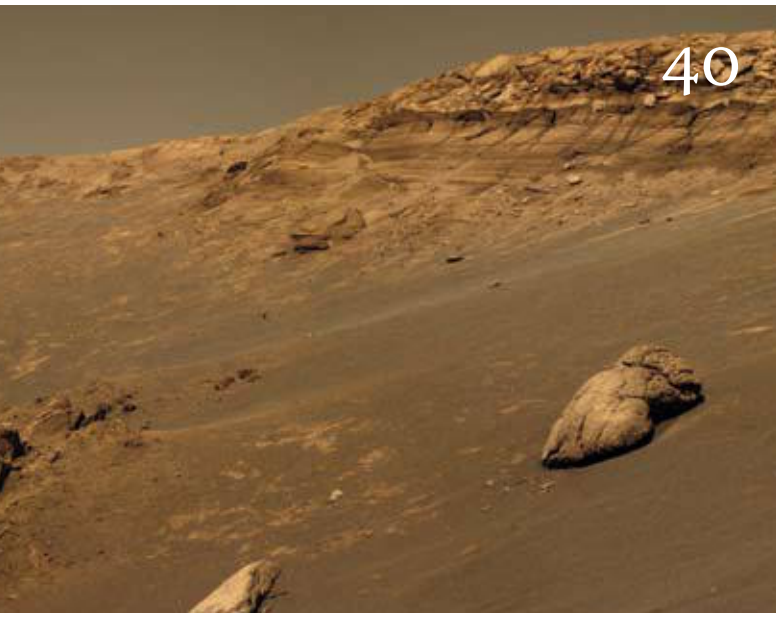


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The news department **Resources** is now located online at Astronomy.com. You will also find additional **Coming events** for your area on our web site.

Astronomy
Volume 33, Number 8

# The ever-weirder universe

## Just when we humans get comfortable

with what we "know," we learn something is different. An example is our understanding of the universe. In 1981, astrophysicist Martin Harwit used his book *Cosmic Discovery* to show that we probably know of only a small percentage of the kinds of phenomena existing in the cosmos. While the Big Bang origin of the universe seems clear to most today, the details of what immediately followed — the moments of history that critically affected the universe — are dull and murky.

In his article "Seeing the dawn of time" (p. 34), Adam Frank of the University of Rochester in Rochester, New York, describes the latest news and research concerning the backbone of cosmology: inflation theory. The brainchild of Massachusetts Institute of Technology's Alan Guth, who was searching for answers to a number of unresolved cosmological riddles in the 1970s, inflation theory has gradually gained wide acceptance among cosmologists.

The theory maintains that a fraction of a second after the Big Bang, the cosmos hyper-inflated from a speck smaller than a subatomic particle to the size of a softball. This inflationary spurt helps reconcile rough edges between cosmology and particle physics, when explaining the universe's early history.

In essence, inflation is the savior of the Big Bang. It resolves issues that can't be explained by the standard Big Bang model — the causality problem, as it's called, of uniform gas temperatures everywhere; the flatness problem, which links the shape of space to the energy within it; and the magnetic monopole problem, which is the fact that no such monopoles exist, although they ought to. With inflation theory, however, these problems, and others, are potentially solved.

Inflation also offers some weirdness of its own. "Even a moment's reflection will tell you there's more cosmos than we can see," writes Frank. In inflation, a "speck of the cosmos gets hyper-expanded into the entire observable universe."

Frank continues, "What about the rest of it? As physicists and astronomers considered that question, they realized inflation may demand that there be a lot more out there."

After you've considered inflation's mind-bending propositions, you may want to check out "Before there was light" by Steve Nadis (p. 46). Contributing editor Nadis describes the amazing ways astronomers are working to trace primordial hydrogen to determine not only when the universe lit up from its early Dark Ages, but how it happened. This epoch — spanning hundreds of millions of years — holds answers to one of cosmology's biggest questions: How did cosmic structure form?

This exciting new stage in understanding the early cosmos is generating a lot of buzz in cosmological circles, and it will continue to be a big story that develops over the coming years.

Yours truly,

David J. Eicher
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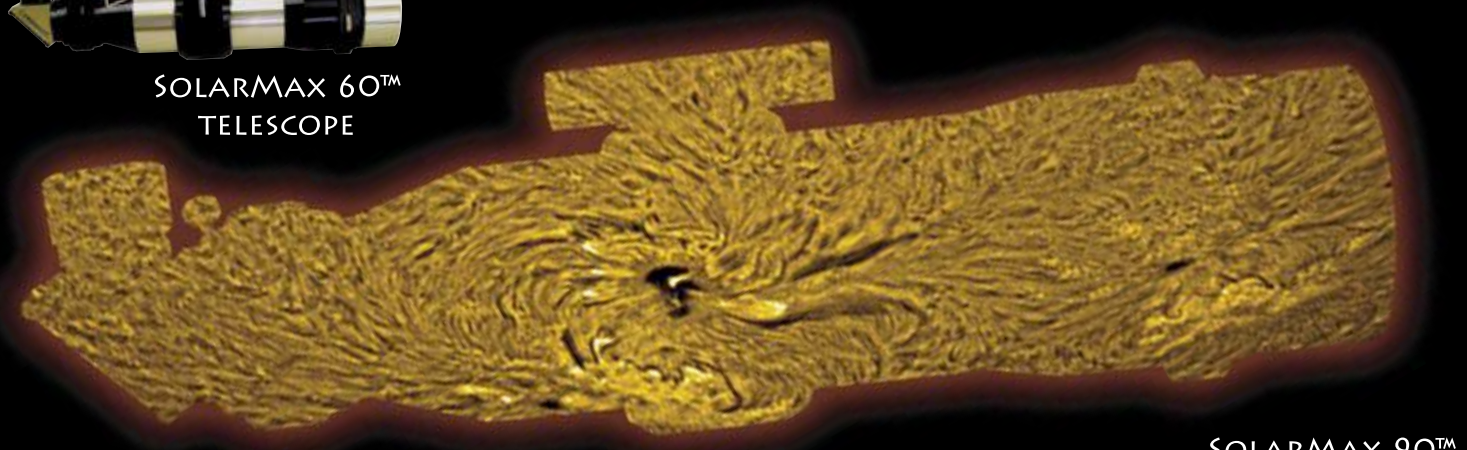

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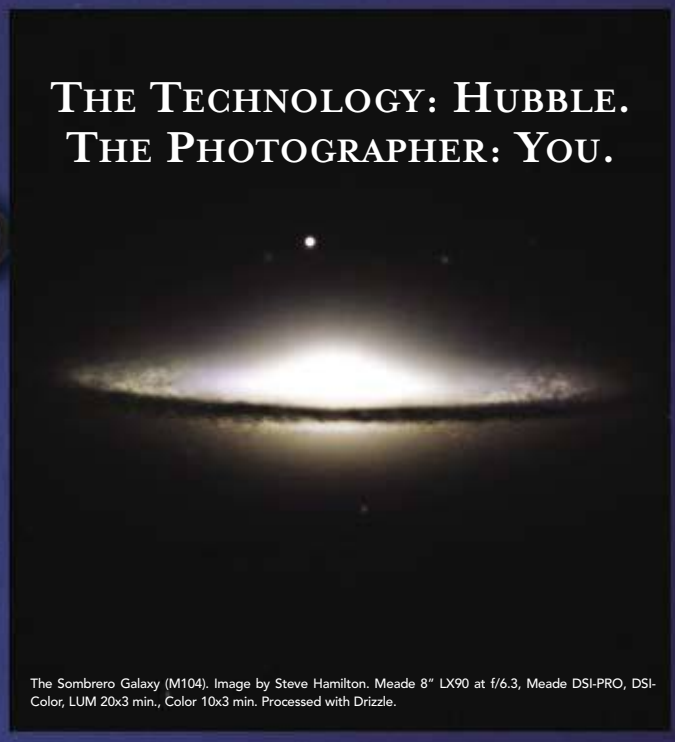

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| 8) Nebular Filters (1.25") – (#908B, #908N, #908X) | $79.95 – $99.95 |
| 9) Variable Projection Camera Adapter (1.25") | $39.95 |
| 10) Anti-Vibration Pads – #895 (Set of Three) | $49.95 |

| LX90™, LX200™GPS & RCX400™ Telescopes | PRICE |
|---|---|
| 1) Series 5000 SWA/ UWA Eyepieces | $179.00 – $449.00 |
| 2) Deep Sky Imager™ | $299.00 |
| 3) Series 5000 TeleXtenders (2x, 3x, 5x – 1.25") (2x – 2") | $159.00 – $229.00 |
| 4) AC Adapter | $80.00 |
| 5) 2" Diagonal Mirror (UHTC™) – #930 | $119.95 |
| 6) Focal Reducers (f/6.3/f/3.3) | $129.95/$149.95 |
| 7) Nebular Filters (#908B, N, X/#911B, N, X) | $79.95 – $149.95 |
| 8) Dew Shields (7"– 16") | $140.00 – $366.00 |
| 9) Flip Mirror 1.25") – #644 | $149.95 |
| 10) Anti-Vibration Pads – #895 (Set of Three) | $49.95 |

| Astrophotography | PRICE |
|---|---|
| 1) Deep Sky Imager™ | $299.00 |
| 2) De Sky Imager PRO | $399.00 |
| 3) Focal Reducers (f/6.3/f/3.3) | $129.95/$149.95 |
| 4) 9mm Illuminate etRcle | $149.95 |
| 5) 25mm CCD Framing Eyepiece | $129.95 |
| 6) Ultra-Wedge (LX90/LX200/RCX400 models) | $375.00 |
| 7) Field De-Rotator (LX200/RCX400 models) – #1220 | $395.00 |
| 8) Tube Balance Weight ystem (LX90/LX200 models) | $105.00 – $190.00 |
| 9) Flip Mirror (1.25") – #644 | $149.95 |
| 10) Anti-Vibration Pads #895 (Set of Three) | $49.95 |

## MEADE AUTHORIZED DEALERS

ANACORTES TELESCOPE
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800-338-9638

RIVERS CAMERA
866-208-1724

TELESCOPES.COM
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# HOT DEALS — Genuine Meade Accessories

NEW

**Save over $250 when you purchase this *Telescope Accessory Kit* together with the purchase of a RCX400™, LX200™ GPS or LX90™ telescope!†**

| Telescope Accessory Kit | $299.00 |
|---|---|
| | **Regular Price** |
| Free TheSky Imager / AutoStar Suite Software | $299.00 |
| f/6.3 Focal Reducer/Field Flattener | 129.95 |
| AC Adapter for RCX400™/LX200™ GPS/LX90™ Telescopes | $80.00 |
| Anti-Vibration Pads - # 895 (Set of Three) | $49.95 |
| **If purchased separately, these accessories would cost over** | **$550!** |

**Save over $100 when you purchase this *Telescope Accessory Kit* together with the purchase of a LXD75™ telescope!†**

| Telescope Accessory Kit | $99.00 |
|---|---|
| | **Regular Price** |
| 14mm 5 Element Plössl Series 5000™ | $89.00 |
| #547 AC Adapter | $69.95 |
| AnIG-Vision Pads - # 895 (Set of Three) | $49.95 |
| **If purchased separately, these accessories would cost over** | **$200!** |

† Valid until July 31st, 2005

## MEADE ACCESSORY KITS

**The telescope accessory kits below can be ordered any time (they do not require the purchase of a telescope).**

### ETX® ACCESSORY KITS

**ETX TERRESTRIAL OBSERVER'S STARTER KIT — $99**
- * SERIES 4000™ 9.7MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 15MM SUPER PLÖSSL EYEPIECE
- * 45° ERECTING PRISM – #932

You save $49!

**ETX CELESTIAL OBSERVER'S STARTER KIT — $99**
- * SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 15MM SUPER PLÖSSL EYEPIECE
- * 2X BARLOW – #126

You save $47!

**ETX AMATEUR ASTRONOMER'S KIT — $199**
- * SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 15MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 32MM SUPER PLÖSSL EYEPIECE
- * 2X BARLOW – #126
- * AC ADAPTER – #541
- * LUNAR & PLANETARY COLOR FILTER SET – #3200

You save $106!

**ETX DELUXE OBSERVER'S KIT — $299**
- * SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 26MM QX WIDE ANGLE EYEPIECE
- * SERIES 4000 32MM SUPER PLÖSSL EYEPIECE
- * 2X BARLOW – #126
- * 45° ERECTING PRISM – #932
- * COLOR FILTER KIT #1
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)
- * MOON FILTER – ND 96
- * AC ADAPTER – #541

You save $163!

**ETX DELUXE ASTROPHOTOGRAPHER'S KIT — $299**
- * 2X BARLOW #126
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)
- * # 64T-ADAPTER
- * SERIES 4000 PLÖSSL 9MM ILLUMINATED RETICLE (WIRELESS
- * AC ADAPTER – #541
- * AUTOSTAR SUITE™ / LUNAR PLANETARY IMAGER™

You save $183!

### rX90 ACCESSORY KIT

**LX90 ASTROPHOTOGRAPHER'S KIT — $249**
- * 8" LX90-WEDGE w ADAPTER PLATE
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)
- * SERIES 4000 f/6.3 FOCAL REDUCER

You save $101!

### LXD75 ACCESSORY KITS

**LXD75 CELESTIAL OBSERVER'S KIT — $199**
- * SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 15MM QX WIDE ANGLE EYEPIECE (70° AFOV)
- * SERIES 4000 26MM QX WIDE ANGLE EYEPIECE (2") (70° AFOV)
- * 2X BARLOW – #126

You save $66!

**LXD75 DELUXE OBSERVER'S KIT — $299**
- * SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
- * SERIES 4000 15MM QX WIDE ANGLE EYEPIECE (70° AFOV)
- * SERIES 4000 26MM QX WIDE ANGLE EYEPIECE (2") (70° AFOV)
- * 2X BARLOW – #126
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)
- * AC ADAPTER – #547
- * MOON FILTER – ND 96
- * COLOR FILTER KIT #1

You save $153!

**LXD75 DELUXE ASTROPHOTOGRAPHER'S KIT — $299**
- * VARIABLE PROJECTION CAMERA ADAPTER
- * SERIES 5000™ 3X TELEXTENDER
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)
- * AC ADAPTER – #547
- * SERIES 4000 PLÖSSL 9MM ILLUMINATED RETICLE (WIRELESS)

You save $170!

### LX90, LX200GPS & RCX400 ACCESSORY KITS

**ASTROPHOTOGRAPHER'S KIT — $349**
- * SERIES 4000 f/6.3 FOCAL REDUCER
- * SERIES 4000 PLÖSSL 9MM ILLUMINATED RETICLE (WITH NoDak)
- * VARIABLE PROJECTION CAMERA ADAPTER
- * #644 FLIP MIRROR SYSTEM
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)

You save $151!

**DELUXE ASTROPHOTOGRAPHER'S KIT — $499**
- * SERIES 4000 f/6.3 FOCAL REDUCER
- * SERIES 5000 2X TELEXTENDER (1.25")
- * #647 FLIP MIRROR SYSTEM
- * SERIES 4000 PLÖSSL 9MM ILLUMINATED RETICLE (WITH CORD)
- * ANTI-VIBRATION PADS – #895 (SET OF THREE)
- * VARIABLE PROJECTION CAMERA ADAPTER

You save $260!

All prices are in U.S. Dollars.

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**CANADIAN RESIDENTS**

**Contact your local Canadian Meade dealer. Or, to purchase from a U.S. dealer:**
1. Add 20% to U.S. price(s) to cover shipping and taxes.
2. Add $50 processing fee.
3. Meade will ship the product directly to your door.

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# LUMICON The World's Best Filters & Astronomical Accessories

*Lumicon International offers the best and most extensive line of astronomical filters in the world. Filters for every imagined visual and astrophotographic application, in many configurations and sizes. Filters for light polluted skies, planets, deep sky objects, galaxies, nebulae, planetary nebulae, comets, and solar prominences. All Deep Sky, UHC, OIII, H-Beta, and Comet Filters are individually tested and proudly inscribed with the percentage of light transmittance of their primary emission lines. Lumicon also offers a complete line of unique accessories, including the World Famous Easy Guider Series, Sky Vector Systems, Diagonals, Finderscopes, and Binocular Viewers. To ensure that Lumicon Products remain the World's Best, the strictest quality control standards are employed throughout the production process. All Lumicon Products are made to the highest standards available and come with a 100% Satisfaction Guarantee - Please Visit www.lumicon.com for Details.*

**DEEP SKY FILTERS** The best light pollution filter on the market today. Blocks all high & low pressure mercury and sodium vapor lamp light, neon lights and airglow, while transmitting the rest of the visible spectrum. Excellent for both visual and photographic applications. Visually, the Deep Sky Filter is most useful under light-polluted skies, from where it reveals faint objects like star clusters, galaxies, nebulae and comets by darkening the background of space. Photographically, the Deep Sky Filter enables deep space photos to be taken through city lights and blocks natural airglow at dark-sky sites, thus improving results in film and CCD astrophotography.

1.25" – $99.95 • 1.25" Questar – $99.95
2" – $199.95 • Cassegrain Rear Cell – $199.95

**ULTRA HIGH CONTRAST FILTERS** The ULTIMATE nebula filter. The original LUMICON Ultra High Contrast Filter is unbeatable for revealing nebulosity. This achievement in filter performance is attributed to exclusively designed coatings that isolate the two doubly ionized oxygen lines (496 and 501nm) and the H-beta line (486nm) emitted by planetary and most emission nebulae. The result is superb views of the Orion, Lagoon, Swan and other extended nebulae. s ful great antage under dark skies.

1.25" – $99.95 • 1.25" Questar – $99.95
2" – $199.95 • Cassegrain Rear Cell – $199 5

**OXYGEN III FILTERS** The legendary LUMICON OIII narrow bandpass filter isolates just the two doubly ionized oxygen lines (496 and 501nm lines) emitted by diffuse, planetary and extremely faint nebulae. Thus, these faint objects become much more visible against the blackened background of space. The LUMICON Oxygen III Filter produces near-photographic views of the Veil, Ring, Dumbbell and Orion nebula, among many other objects. Performs best under both light-polluted and dark skies. You will be amazed at what the OIII filter allows you to see!

1.25" – $99.95 • 1.25" Questar – $99.95
2" – $199.95 • Cassegrain Rear Cell – $199.95

**HYDROGEN-BETA FILTERS** The Horsehead Nebula filter. The LUMICON H-Beta Filter isolates only the hydrogen-beta line of the spectrum (486nm) in a narrow pass-band just 9 nm wide. The result is extreme contrast between the black background of space and the delicate Hydrogen - Beta emission of extended nebulae. Now you can view extremely faint, special objects such as the Horsehead, Cocoon and California Nebulae. In many cases, the LUMICON H-Beta Filter is the ONLY way to view these objects. A transparent sky, a 8" or larger telescope, and the LUMICON H-Beta Filter, will tremendously aid in viewi g t os " otch in thg b lt" objec

1 5" – $99.951.25" Questar – $99.95
2" – $199.95 • Cassegraih Rear Cell – $199.95

**COMET FILT RS** he LUMICON Comet Filter, a narrow bandpass ystem (25nm), isllates the 501nm OII line and b th Cyano en line1 ao 511n a o 514nm. The high contrast gain of the filter re al the delicate ionized tail of gaseous comets, allowing you to see their full extent. The Comet Filter also helps you to b tt r dis inguish gaseousi comets from dusty omed hioh normally show little contrast gain.

Howard Brewington, x e comet disco erer, say : "I d ycovered Come Aarseth-Brewing n, 19 ik , using the LUMICON Comet Filter. The filter doubled the contrast, making the comet very easy to spot." Why mRkL comet-hunting harder than it needs o be?

1.t " – $99.95• 25" Qtestar – $9 .95
2" – $199.95 • Cassegrain Rear la – $199.95

**NIGHT-SKY H IOGEN- LPHA FILTERS** Not intended for solar observing, the LUMICON Night-Sky H-Alpha Filte is a o-erful ph o raphic aid ineovercoming light pollution during de n-s y photography. It will greatly reduce light poll tion, making it t eal for photography of f int emission ae. tExposures may be increased up to 10 i e ithout diminis ing the black background in your photograph, thus, achieving strikingly improved results in black & white il and CCDiastrophotogr p y. Both mib su f es ave high light transmittanNewcoatings for aximum performance.

2" – $6 .95•p58mm – $79.95 • 57mm – $89.95 • 8 mm " 99.95

**MINUS I T FILTERS** ? ICON Minus V5olet Filter g e t y impro es phutographs taken throu h lens systems, produ an pinpoint star images. It is espe ially recommended for all telephoto lenses. The Minus Violet filter passes the maximum amo nt of visible light, including the full blue, green, yellow and ed po ti s f the spectrum. It absorbs violet and ultraviolet light below e20nm othus eliminating blue alos around bright stars in color photography. In B&W photography et eliminates bloated in swollen star mages Ou ed by violet and ultraviolet light, which te epheto lenses cannot focus perfectly, due to chromatic aberration. This filter is unsurpassed in op otogtap ic p rformance.

2" – $69.95 • 58mm – $79.95 • 72mm – $89.95

**LUNAR AND PLANETARY FILTERS** LUMICON Lunar and Planetary filters are made from renowned Schott and Hoya optical glass. Each filter is individually precision ground and highly polished with ultra-high light transmittance coatings on both sides for ultimate contrast on lunar and planetary detail. Double stacking filters may also improve lunar imaging. Optimized for both visual and photographic applications. For a complete list of lunar and planetary filters and applications, please visit www.lumicon.com. 1.25" – $19.95 • 2" – $29.95

**POLARIZING FILTERS** LUMICON P larizi g Fil er ar manuf 5ueed from optically flat Hoya polarnzed gya s. Performs bes Pt cutting4all gla e and increases ontrast n bright celestial obje ts such as the moon at full illumination and can be double-stacked with t er LUMICON filters for use on bright planets. They are also useful for daylight observation of land, sea and nature. In addition to polarizing the light, they reduce its intensity by a factor of about 3. Also available in rotating polarized cell designs for variable levels of light transmittance to any value between 5% and 30%.

Single Polarizer 1.25" – $29.95 • 2" – $39.95
Variable Polarizer 1.25" – $39.95 • 2" – $49.95

## • NEW • NEW • NEW •

**80MM SUPER FINDER SYSTEM** The highest quality finder system on the market today, the newly redesigned LUMICON 80mm Super Finder features exceptionally sharp optics, high contrast views and easy to use functionality. The LUMICON 80mm Super Finder is designed to switch conveniently from straight through to right angle in seconds with supplied extension adapter. Includes a front barrel focuser for fast and precise focusing. In addition, the LUMICON 80mm Super Finder includes a correct image right angle diagonal for hassle free pointing in any direction.

The LUMICON 80mm Super Finder also doubles as a high quality rich field refractor, yielding superb views of the moon, planets, star clusters, bright galaxies as well as daytime images. Use it with the optional Image Visor and reduce glare while increasing contrast and resolution on lunar and terrestrial views.

Objective Lens: Fully Multi-Coated 80mm Achromatic Lens; Focal length: 300mm; Includes a Quality 25mm Kellner Crosshair Eyepiece; Super Finder System Weight: 2.7 lbs. Body color available in Black or White.

80mm Super Finder System – **$299.95**
80mm Super Finder Body (Body Only) – **$219.95**
Image Visor – **$24.95**
2X Fully Coated Barlow Lens – **$39.95**

**UNIVERSAL DOVETAIL FINDERSCOPE BRACKETS** The LUMICON Universal Dovetail Finderscope Bracket will securely hold your finderscope to your telescope. The dovetail design permits fast removal and reinstallation of your finderscope while maintaining the alignment to your telescope. Mounts on most telescope tubes, with adjustments for other tube designs. Made from solid aircraft aluminum.

50mm Universal Dovetail Finderscope Bracket – **$49.95**
80mm Universal Dovetail Finderscope Bracket – **$59.95**
Universal Dovetail Bracket Spare Base – **$14.95**
Universal Dovetail Bracket Tripod Mounting Base – **$19.95**

**MULTIPLE FILTER SELECTORS** LUMICON Multiple Filter Selectors allow you to switch back and forth between filters without having to thread and unthread them from your eyepieces or diagonal. The nose-piece also has threads, so one filter, such as a neutral density or polarizing filter, can be "stacked" with the others. Leaving one of the slots open lets you compare views with and without your LUMICON filters. Made from solid aircraft aluminum.

1.25" Multiple Filter Selector Features: Fits Standard 1.25" Filters; 5 Filter Positions; 6oz Light Weight Construction; 5/8" Low Profile Design; Includes 1.25" Eyepiece Adapter and T-Thread Adapter. Price – **$129.95**

**NEW** 2" Multiple Filter Selector Features: Fits Standard 2" Filters; 4 Filter Positions; Light Baffles for Astrophotography; 8oz Light Weight Construction; 5/8" Low Profile Design; Includes 2" Eyepiece Adapter and Male Cassegrain Rear Cell Adapter. *Filters sold separately.*

***Introductory Price:*** **$169.95**

**ADVANCED CLEANING KIT** The very best cleaning kit ever offered. The LUMICON Advanced Cleaning Kit has everything you need to clean even the most delicate lenses and mirrors. Safe to use on all optical surfaces. Includes LUMICON Lens Cleaning Spray, LUMICON Multi Coated Optics Cleaning Fluid, LUMICON Lens Cleaning Tissue, Ultra Brush Dust Remover, Air Blower Blush, 100% Cotton Swabs, LUMICON Micro-Fiber Cleaning Cloth, "Blow Off" Compressed Air and a Hard Carrying Case.

***Introductory Price:*** **$39.95**

**SOLAR PROMINENCE FILTER SYSTEM**

The LUMICON Solar Prominence Filter System converts your existing telescope into a Hydrogen – Alpha solar telescope. Viewing the sun in Hydrogen – Alpha light allows for amazing images of solar prominences, solar flares, sun spots, bright filaments and other surface features. Simply use a standard camera T-Ring and SLR camera for full photographic capability. Safely observe and photograph the sun at high and low powQs d re tly through your own telescope.

The UMICON ol r Prominence lter System includes three components: 1. The Energy Rejection Prefilter; blocks all harmful radiation before it enters your telescope. 2. The Off-Axis Mask; stops down your objective and holds the Energy Rejection Prefilter. 3. The SPF Body; extremely narrow-band (1.5 Angstrom) Hydrogen-Alpha filter, provi i g high contrast imaging of solar features. This portion of the filter slidCs into a 2" focuser or diagonal. Includes a T-Thread camera adapter and a 1.25" eyepiece adapter.

Solar Prominence Filter System for 7" / 8" Cassegrain – $779.95 • Meade 10" SCT – $789.95 • Celestron 11" SCT – $799.95 • Meade 12" SCT – $809.95 • Celestron 14" SCT – $819.95 • Meade 14" SCT – $819.95 • Meade 16" SCT – $899.95

Solar Prominence Filter Kit available for telescopes not listed here. The Off-Axis Mask is not included and can be fabricated by customer. Price - $699.95

For more information, visit www.lumicon.com

**DIAGONALS**

**Enhanced Mirror Diagonals**

With 96 - 97 percent light reflectivity, 1/10 wave precision polished optics and individually performed double pass collimation tests, the LUMICON Enhanced Diagonal is a must for a fast and significant upgrade from any standard prism diagonal. Includes standard filter threads for trouble-free changing of eyepieces and accessories while using filters. Made from solid aircraft aluminum.

1.25" Enhanced Diagonal - $99.95
2" Enhanced Diagonal - $189.95

**LumiBrite Mirror Diagonals**

With greater than 98 percent light reflectivity, 1/10 wave precision polished optics and individually performed double pass collimation tests, the LUMICON Lumi-Brite Diagonal maximizes the performance of your telescope for ultimate contrast and resolution one can get from a star diagonal. The exceptional Dielectric Coating provides for a more durable and longer lasting surface. Additionally, objects appear much brighter, with truer color. Includes standard filter threads for trouble-free changing of eyepieces and accessories while using filters. Made from solid aircraft aluminum.

1.25" LumiBrite Diagonal – $149.95
2" LumiBrite Diagonal – $239.95

**Prism Diagonals**

1.25" Multi-Coated Prism Diagonal – $49.95
1.25" 90° Correct Image Diagonal – $69.95

**BINOVIEWER**

The LUMICON BinoViewer allows you to comfortably use both eyes while looking through your telescope. The efficiently designed light beam splitter allows for minimum light loss and improved image contrast up to 40 percent. The LUMICON BinoViewer uses precision polished, Grade-A BK 7 crown glass with the highest contrast and color correction available. Its fully multi-coated optics and roof prism design provides for maximum light transmittance, freedom from ghosting images, and built in image correction. Installs in seconds into standard 1.25" focusers or diagonals. Eyepieces not included.

Specifications: Clear Aperture: 22mm; Focus Travel: 20mm; 1.25" Barrel, Threaded for Filters; Magnification: 1X; Overall Length: 120mm; Weight: 23 oz.

Price – $799.95

**EASY GUIDERS SYSTEMS**

The most powerful astrophotographic accessory available today. LUMICON Easy Guiders feature patented radial and rotational off-axis adjustments, combined with a large off-axis pick off prism, selecting bright guide stars becomes a breeze for manual astrophotography or computer controlled auto-guiding.

**Newtonian / Refractor Easy Guiders**

The LUMICON Newtonian/ Refractor Easy Guider allows off-axis guiding directly through the main telescope, preventing differential flexure between your telescope and guide scope, which can ruin your astrophotos. The low profile design installs in seconds into standard 1.25" and 2" focusers. Accommodates standard filters and camera T-Rings.

Newtonian/Refractor Easy Guider 1.25" – $189.95
2" – $189.95

**Cassegrain Easy Guiders**

The LUMICON Cassegrain Easy Guider allows off-axis guiding with your 5" – 9.25" cassegrain telescope. The included multi-coated 50mm focal reducing lens reduces the f-ratio from f/10 to f/6.5 or f/5, providing a wider field of view, increased edge flatness and shorter exposure times. The faster f-ratio combined with the ease of finding and guiding on bright stars, minimizes guiding error, making for successful astrophotos. Accommodates standard 2" filters and camera T-Rings.

Cassegrain Easy Guider for Celestron 5" – $249.95 • 7" - 9.25" – $249.95

**Giant Easy Guiders**

The LUMICON Giant Easy Guider is a very powerful photographic and visual tool. Utilizing a large multi-coated 80mm focal reducing lens, the f-ratio of your telescope is reduced from f/10 to f/6.5 or f/5, thus, increasing your field of view and edge flatness as wells as decreasing exposure times. Unlike other focal reducing lenses, the LUMICON Giant Easy Guider has full frame illumination and pin-point star images on 35mm film, 120 format film and large format CCD cameras. Accommodates standard 2" filters and camera T-Rings. Meade 16" LX200 requires separate adapter.

Giant Easy Guider Meade 10" - 16" SCT – $399.95 • Celestron 11" - 14" SCT – $399.95

**Easy Guider Accessories**

Cassegrain Easy Guider SCT Accessory Adapter – $39.95 • Giant Easy Guider Adapter to Meade 16" LX200 – $169.95 • F/10 Viewing Adapter – $89.95 • SCT Accessory Adapter – $49.95 • Helicoid Focusable Off-Axis Tube – $79.95 • Giant Easy Guider Adapter Ring for Meade or Celestron – $49.95 • Newtonian/ Refractor Easy Guider 2" Threaded Focal Reducer – $79.95

**CAMERA T-RINGS**

Canon, Canon EOS, Konica, Minolta, Minolta Maxxum, Nikon, Olympus, Pentax-K, Pentax-S – $19.95

**EYEPIECES AND ILLUMINATORS**

25mm Fully Multi-Coated Kellner Crosshair Eyepiece – $69.95 • 12.5mm Orthoscopic Eyepiece with Illuminated Reticle – $149.95 • Pulseguide Illuminator – $49.95

**CAMERA ADAPTERS**

Prime Focus Camera Adapters: .965" – $19.95 • 1.25" – $24.95 • 2" – $49.95 • Eyepiece Projection Camera Adapters: .965" – $39.95 • 1.25" – $39.95 • 1.25" Eyepiece - T-thread Adapter – $29.95 • 2" – $49.95 • 2" Male Adapter w/ Filter Threads to Male T-Thread – $29.95 • Cassegrain Tele-Extender – $29.95

**UNIVERSAL DIGI-CAM ADAPTER**

The most versatile digital camera adapter available today. Attach any digital camera, with a standard 1/4" x 20 tripod thread, directly to your telescope or spotting scope. Includes fine motion controls for precise alignment. No tripods or brand specific T- Ring necessary. Made from solid aircraft aluminum.

Price: $39.95

**DELUXE PIGGYBACK MOUNTS**

The LUMICON Deluxe Piggyback Mount allows you to mount cameras or small telescope having 1/4" x 20 threads, onto medium and large telescopes. The LUMICON Deluxe Piggyback Mount is adjustable in altitude and azimuth, thus allowing you to align your camera with the optics of your main telescope. Four radii available for closest fit to your telescope tube.

Deluxe Piggyback Mount 6" – $59.95
Deluxe Piggyback Mount 8" – $59.95
Deluxe Piggyback Mount 10" - 12" – $59.95
Deluxe Piggyback Mount 14" – $59.95

**RICH-FIELD VIEWERS**

**Cassegrain Rich-Field Viewers**

The LUMICON Rich-Field Viewer takes your cassegrain's f/10 optics and reduces it to f/6.3 for beautiful low power, wide-angle views. Its multi-coated reducing lens has a large clear aperture, less coma than higher priced focal reducers on the market, while providing superb unvignetted views. Accommodates 2" diagonals and accessories.

Cassegrain Rich-Field Viewer for 5"-9.25" – $99.95

**Giant Rich-Field Viewers**

The same high quality 80mm multi-coated optical system and fine machining of LUMICON's famous Giant Easy Guiders are incorporated into LUMICON's Giant Rich-Field Viewer. Converting your cassegrain's f-ratio from f/10 to f/6.5 or f/5 provides for the maximum brightness and field of view your telescope allows. Ultimately, this feature will allow for the widest possible views of large galaxies like the Andromeda Galaxy, the Triangulum Galaxy, NGC 253, and pairs of galaxies like M81and M82. Accommodates 2" diagonals and accessories. Meade 16" LX200 requires separate adapter.

Giant Rich-Field Viewer Meade 10"-16" SCT – $279.95 • Celestron 11"-14" SCT – $279.95

**SKY VECTOR SYSTEMS**

The LUMICON Sky Vector System is a state-of-the-art digital setting circle system, providing virtually any astronomical telescope, whether equatorial or alt-azimuth, with a continuous, real-time digital readout of right ascension and declination coordinates. With the LUMICON Sky Vector, you will be able to find objects even faster than with most fully computer-driven telescopes. Its alphanumeric display uses a simple, easy-to-read scrolling text format. There is no need to polar align or to enter Latitude, Longitude, Date, Altitude, and Sidereal time – just initialize on one or two stars and you're ready to go! Includes Mounting Hardware.

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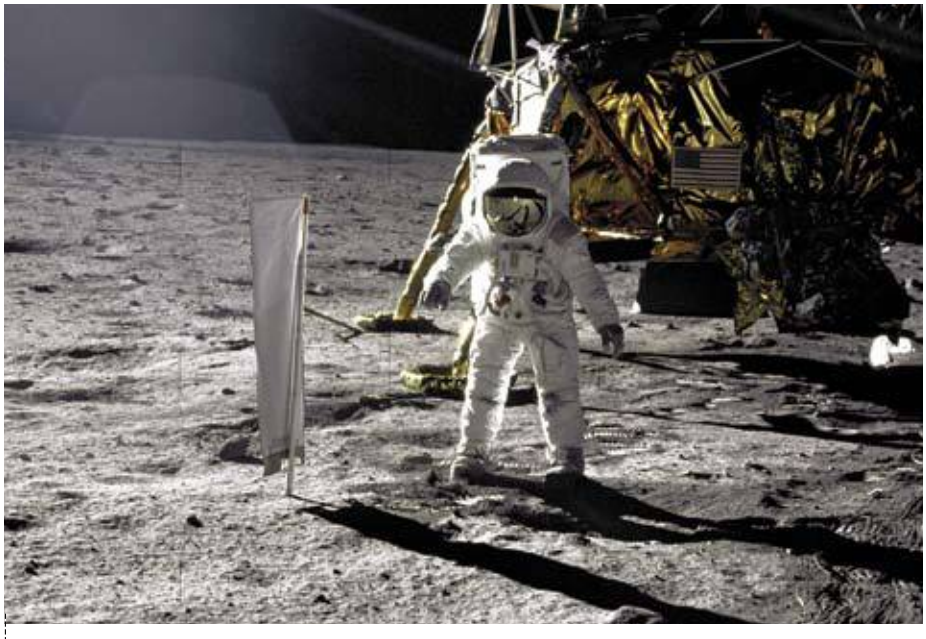
# Space Buzz

Thank y u for the Buzz Aldrin Ln1er-view (May 2005). AlVhoughFAldrin se ms ov rly optimistic at times duri g the discussion, his direct approach is refreshing. He could easily rest on his laurels as a moon-walker, but Aldrin remains involved in space exploration. He was a member of NASA's third astronaut group. Now, Aldrin is



NASA

**BUZZ ALDRIN,** seen here on the lunar u face in 1969, believes the next step in the Moon-to-Mars ini ,ive should be to complete the International Space Station.

devoted to space tourism, and his company designs rockets. Bridging the past and future, he is the perfect advocate for space exploration. I hope that space-agency officials read this interview. — **PETE BEICH,** KNOXVILLE, TENNESSEE

our informative interview with Buz Aldrin touches on his military career. I think this background shines through in his candor — direct, no-nonsense answers based on a goal-oriented vision. It is clear that Aldrin isn't a politician. — **JAMES CRAMPTON,** FARMINGTON, UTAH

I am disappointed that Buzz Aldrin answered a different question rather than addressing your international cooperation in space inquiry.

I wanted a reply based on Aldrin's experiences as a former astronaut and owner of a rocket-design company. Instead, he spoke of potential benefits from the burgeoning Chinese space program competing against Russia. Watching nations play off one another sounds like a Cold War application.

The space race is over. To achieve in space, I believe the United States will be most successful through actively pursuing global cooperation, not reaping the rewards of long-term competition. — **JONATHON PALMER,** TORONTO

## Great influence

I was pleasantly surprised to find "The sky's knight" (May 2005) in *Astronomy.* Those unaware of Sir Patrick Moore can't understand what he has meant to astronomy and Great Britain.

Like many others, I was introduced to astronomy through Moore's British Broadcasting Corporation show, *The Sky at Night.* Moore has a terrific ability to communicate astronomy to young and old — I even remember him visiting a children's program, *Blue Peter,* when I was younger.

Through his work, Moore maintained my interest in observing even when it was nearly impossible to find appropLiate lo- a tions or conditions. The longtime joke here is that Moore is single-handedly responsible for keeping a clouded-over nation fascinated by the night sky. — **EDWARD LIPTON,** MANCHESTER, ENGLAND

## Corrections

On page 76 of "The sky's knight," Sir Patrick Moore is standing outside his backyard observatory in Sussex, not outside the Armagh Planetarium, as stated in the caption.

In our news story, "The astronomy of launching a shuttle" (May 2005), the description of daylight's impact on launch times was incorrect. Please visit Astronomy.com's news section to read a detailed explanation. — ***ASTRONOMY* EDITORS**

*We welcome your comments. Send letters to* Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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BY BOB BERMAN

# The masked ball

**Some of us will take breaks from this month's midnight meteors to look through telescopes. We'll peer at all sorts of shapes.** For untold millennia, people gazed at a sky dominated by two perfectly round objects. But now, through telescopes, we rarely see anything truly round. Jupiter's wild 28,000-mph rotation gives its equator a pronounced bulge. Saturn is even more oval. Venus and Mars currently show gibbous phases. Clusters, stars, galaxies — none of them looks perfectly round either.

Despite all that, the sphere is the universe's most common shape. Why don't stars instead look like disks, cigars, or cubes? Answer: A sphere alone has a surface where every spot lies the same distance from the center. Its exterior has the smallest possible area. You need more paint to cover a cube or diamond than a ball of equal weight.

So when a gas cloud or solid body contracts from its own self-gravity, it pulls itself into the smallest possible form, and that's always a ball. Only things with little mass, like tiny moons or asteroids, lack enough gravity to do the job.

If the object spins quickly, its equator may bulge out and it'll be thrown out of the ball club. The Sun's strangely slow 4-week rotation lets it keep its lovely round figure. Our lethargic Moon (which also has a 4-week spin) differs from a perfect sphere by just one part in 500. To the eye, the Full Moon is indistinguishable from a perfect disk. It's not the slightest bit out-of-round.

This pleased ancient cultures, who regarded the circle as nature's ideal shape. Yet you never found flawless disks on Earth. Only in the heavens, with the Sun and Moon, was such perfection beheld. And both of those appeared the same size! The Moon would even sometimes place itself precisely over the Sun to produce the total eclipse.

What magic was that!

Ancient cultures also noticed the Moon's disk shifts against the background stars in 1 hour. The Sun's disk moves its diameter in 1 day, and again in 1 night. It all seemed so perfect.

Nowadays, we know that the most perfect spheres are neutron stars, the nearest of which is 300 light-years away. Each of these ultraheavy balls has a density equal to a loaded freight train crushed down to the size of the period at the end of this sentence. Flawless superhard globes 12 miles wide, their solid glowing surfaces cannot be blemished by any possible method. Hit one with nuclear missiles and it wouldn't scratch or dent. They are indestructible.

> The night is dark because the universe is young.

Math-o-phobics might confront their fear by tackling the formula for a ball's volume. It's $4.19 \times \text{radius}^3$. Use it to find the volume of the Sun quickly, or how much space exists in the vast sphere between Earth and some galaxy. The main result is that as you look farther and farther away, the amount of space increases wildly, and so does the number of stars or galaxies.

Let's try an example. There happen to be 100 stars nearer to us than 20 light-years. Say we want to know how many stars lie within 2,000 light-years, roughly as far as the star Wezen in Canis Major. Easy. 2,000 light-years is 100 times farther than 20 light-years. So we cube 100 (100 x 100 x 100) and find the new volume of space is a million times greater than the old. Since 100 stars lie within 20 light-years, 100 million stars thus should exist between Wezen and us. (Most are invisibly faint.)

Two quick conclusions emerge from this. First, most of the universe lies very far away. Second, because the image or light from the newborn Earth is only now reaching a distance or radius of 4.5 billion light-years from here, more than 95 percent of the universe's stars and planets cannot possibly see us no matter what kind of telescope aliens might build there, because our light hasn't yet reached them! We're invisible to most of the cosmos.

Pondering the volume of the sphere of space centered on Earth, German astronomer Heinrich Olbers realized 2 centuries ago that stars increase with distance cubed, while star-brightness only fades with distance squared. Bottom line: The huge numbers of faraway stars should more than make up for their dimmer appearance, and the night sky should blaze with brilliance. Stars ought to fill every tiny piece of sky. The dome of night should have the same brightness as the Sun's surface.

Neither Olbers nor anybody for the next several lifetimes could figure out why the sky is dark, though lots of people went around in circles trying. Finally, we have the answer.

Mostly, it's the same reason much of the universe cannot see us: There hasn't been time for light from virtually all the universe's stars to get here. The night is dark because the universe is young.

It's one enormous masked ball.

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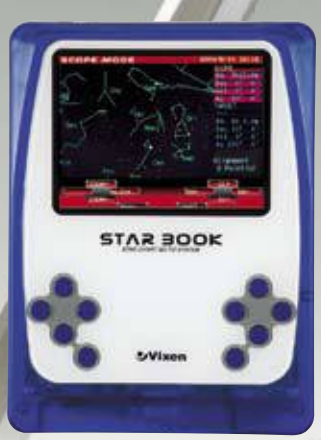


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BY GLENN CHAPLE

# Summer sledding

**The summer Milky Way dominates the evening sky in August. What a grand sight it is — a bright band of light arching high overhead to the north from Cassiopeia, then southward to Sagittarius. ☾ Well, at least that's how I remember it. ☾ When I moved to rural Massachusetts 30 years ago, the summer Milky Way from my** backyard truly was awe-inspiring. But as the surrounding community grew, so did the light pollution. A town-wide lighting ordinance passed a few years ago came too late to save the once-pristine skies. Like many of you unfortunate souls, I have to trek to remote sites to get my Milky Way "fix."

Fortunately, the local light pollution isn't so severe that I can't sail along the Milky Way with binoculars or a telescope. One of my favorite Milky Way ports-of-call is an asterism — a small grouping of stars in the night sky — I call the "Sleigh." Located on the boundary between **Aquila** and **Scutum** (see finder chart below), it's visible to the unaided eye from dark-sky locales.

The Sleigh's front centers on the star **Lambda (λ) Aquilae**, while the back pokes into Scutum. If you scan the Sleigh with binoculars, you can spot a small misty glow. This is the **Wild Duck Cluster (M11)**, so named because its telescopic appearance reminds some viewers of migrating ducks.

A spellbinding sight in any telescope, the Wild Duck Cluster contains more than 100 stars glowing at magnitudes 11 to 14 in an area 15 arcminutes (½ Moon diameter) across. An 8th-magnitude star near the cluster's center most likely is a foreground object.

Also sprucing up the view is a wide double star just off the cluster's southeast edge. I visit this sight again and again.

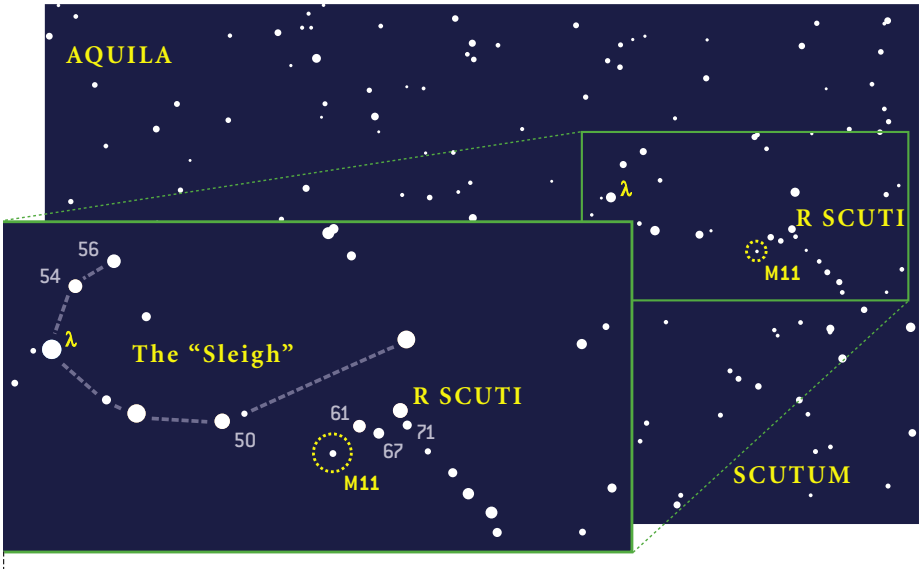


ILLUSTRATION: *ASTRONOMY*; JAY SMITH/MAGNITUDES COURTESY AAVSO

**USE THIS FINDER CHART to find the objects discussed in this article. To further your exploring, be sure to check out the all-sky map on page 53.**

Nestled nearby is the variable star **R Scuti**. It's a sentimental favorite, because it was the first variable star for which I reported magnitude estimates to the American Association of Variable Star Observers (AAVSO). R Scuti is an RV Tauri-type star — a variable class that undergoes alternating bright and faint minima.

During its 5-month cycle, R Scuti varies from magnitude 4.5 at maximum brightness to 6 during a shallow minimum, and 8th magnitude or fainter during a deep minimum — a range within the reach of most binoculars. A chart for R Scuti appears on this page, along with the magnitudes of nearby comparison stars (magnitudes are shown without decimal points; so, magnitude 5.6 appears as 56). An observation every 5 to 7 days will suffice.

## The Ring Nebula

A year ago, I featured the Ring Nebula, M57, in Lyra ("A ring and a triangle," August 2004). Large and bright, M57 is a fine example of a planetary nebula.

Some of you questioned my opinion that to see the Ring and not just a uniformly hazy oval, you'll need a telescope of at least 6 inches in aperture.

With a 4-inch reflector, I barely perceive a hint of darkening near the center, but never enough to convince me it's the real deal. Maybe I'm being too picky. As I've said in the past, I describe objects based on what a beginner, using ordinary equipment under average sky conditions, might expect to see. When you peer into the eyepiece, always see what *your* eyes truly see, not what someone else suggests you should.

Special thanks to David Guibert, who spent time observing M57 with his telescope and forwarding observing reports to me. Dave, you've become an M57 expert.

Next month: Swimming with the Dolphin, and a cheapskate's guide to observing Mars. Clear skies.

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# I'm a little teapot…

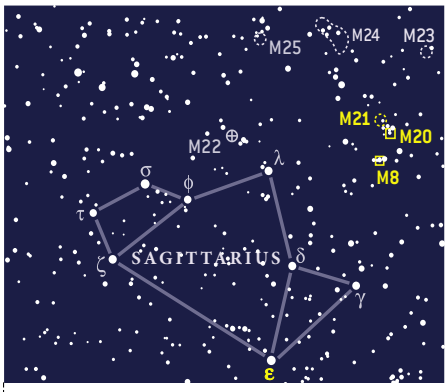
an es are good ATat you learned that poem as a child. But tonight, those words from our yo $h inspire usQ o look up at the summer night sky. Tonight, a celestial teapot gets all steamed up and pours out into the eave . Of course, I am referring to the constellation Sagittarius. Ancient eyes strained to see a centa r aimingsa bow afd arrow at the - r Antares, the Scorpion's heart. Today's stargazers find a teapot among the pattern's eight brightest stars. This month, just as the poem says, Q e kettle must be boiling because we cRn see the steam rising out of the teapot's spout and crossing the sky.

The "steam" is the gentle glow of our Milky Way Galaxy. In fact, when we look toward Sagittarius — these evenings visible from mid-northern latitudes scraping along the southern horizon — we look toward the galaxy's crowded center. This area overflows with many wonderful deep-sky objects. The three targets profiled here this month lie so close to one another that they fit within the same binocular field.

## Lopsided Lagoon

Let's begin with the finest bright nebula in the summer sky the **Lagoon Nebula (M8)**. The Lagoon lies about a binocular field west (to the right) of the star Kaus Borealis (Epsilon [ε] Sagittarii), at the tip of the teapot's top. First, use the finder chart on this page to help locate the star in binoculars, and then look toward the western edge of the field. You should spot several stars enmeshed in a glowing cloud. Many of those stars belong to the open cluster NGC 6530, which is forming within the Lagoon.

Careful examination should show that the Lagoon isn't uniform, but instead looks a little lopsided. The western side glows more brightly and appears more bulbous than the eastern half. A lane — or "lagoon" — of obscuring dust divides the nebula.




TH 8 FIN R G to help locate objects inside and around the "Tea o ."

Spotting the dark lagoon with binoculars presents a challenge, but it can be found with good eyes, steady hands, and dark skies.

Studies suggest M8 spans 140 by 60 light-years. The hydrogen gas that formed the Lagoon is ionized, which means it bursts into fluorescence by the energy from the stars within. Those same stars create strong stellar winds that spawn funnel-shaped clouds resembling tornados here on Earth. Although they remain hidden to backyard stargazers, the Hubble Space Telescope shows the funnel clouds in amazing detail, with each measuring about half a light-year in length.

## Three-part nebula

Now, without moving your binoculars, look less than half a field north of the Lagoon to find a small diamond-shape pattern of stars. The southernmost star in the diamond actually is surrounded by a second, much smaller patch of nebulosity known as the **Trifid Nebula (M20)**.

Unfortunately, while the Trifid shows up in photographs beautifully, its small size means it appears as a tiny glow through binoculars. You'll need at least 50x to spot the three dark "lanes" that led the 19th-century astronomer John Herschel to christen it the "Trifid," from the Latin *trifidus*, "split into three."

## Young starlight

Finally, be sure to visit open star cluster **M21**, just to the northeast of M20. The group consists of several dozen stars. Most binocula wil sh w som f the brightsr cluster members, with the rest blending into a soft glow. By t d -ng t e pectra of those stars, astronomers know them to be hot, blue-white suns with an overall age of only 4.5 million years.

To put that in perspective, in January 2005, Indiana University scientists unearthed skeletal fossils of a human ancestor believed to have lived about 4.5 million years ago. Something to ponder as you gaze skyward tonight.

These objects, all captured in the same binocular field, are a few examples o$kw at await you towa d tne center of oM ga a y. Be sure to stop by Astronomy.com for some other suggested targets in and around Sagittarius. And while you're online, drop me a line and let me know what luck you've had s otting them.

Nex month, we will travel northward along the Milky Way for a look at the celestial shie d o P xand's King Sobieski III (162q–16 ) Until th n, remember, two eyes are et e thas !

**ONLINE EXTRA** Found the three target objects? Other trea s await at www.astronomy.com/toc

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FIRST BURST. Astronomers have detected for the first time a blast of infrared light from the initial explosion of a gamma-ray burst, GRB 041219a. These powerful eruptions have been previously known to emit only gamma rays and X rays.

# news 08

The first extrasolar planet imaged, more moons for Saturn, Russian-American space cooperation, Chandra observes interacting stars, and bottling the Big Bang

NASA/JPL-CALTECH, R. HURT

**WARPED AFTERMATH. This view of the Sombrero Galaxy (M104) in Virgo combines images from the Spitzer and Hubble space telescopes. The equatorial dust disk shows a slight warp that probably resulted when M104 devoured a smaller galaxy that came too close.**

26 **First short gamma-ray burst located**

28 **X-ray flares guard planets**

30 **Astronomy club wins use of giant telescope**

32 **Magnified quasars boost Einstein theory**


## Spitzer probes the Sombrero Galaxy

Astronomers using the infrared-sensitive Spitzer Space Telescope took deep images of the Sombrero Galaxy (M104) in June 2004 and January 2005.

This giant galaxy, 50,000 light-years across, lies about 28 million light-years from Earth and contains as much mass as 800 billion suns. A billion-solar-mass black hole lies at its heart. We see it only about 6° from edge-on.

Combining the recent Spitzer images with earlier ones from the Hubble Space Telescope (taken in May and June 2003) reveals unique details. Note that the equatorial band of dust (glowing red in the Spitzer image) shows a slight warp.

Spitzer's infrared view traces the dust and penetrates the haze, uncovering stars on the ring's inner side, while the clumpy areas are regions of star formation. — **ROBERT BURNHAM**

NASA/STScI

**EDGE-ON VIEW. Caught by the Hubble Space Telescope in visible light, M104 shows its classic form.**

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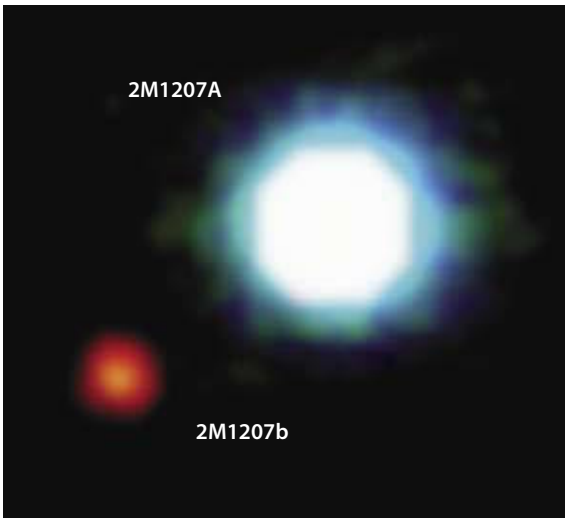
EXOPLANET STAND-IN. Scientists are studying earthlight — light from Earth that fills the un-sunlit part of the Moon — to see how detectable Earth's water and chlorophyl would be to a spectrograph hunting planets in the infrared.

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**REAL PLANET. Brown dwarf star 2M1207A, 170 light-years from Earth, has a planet, "b." The planet orbits 40 AU from the star, taking 1,500 years for one circuit.**

# First exoplanet imaged

A team of astronomers has confirmed that a faint speck imaged last year near a brown dwarf is the first picture of a planet beyond the solar system. The announcement ends a priority dispute (see News, July 2005).

"Our new images show convincingly that this really is a planet, the first ever that's been imaged outside of our solar system," says leader of the discovery team Gaël Chauvin (European Southern Observatory).

Last September, the same researchers reported a reddish speck near the brown dwarf on an image taken with the European Southern Observatory's Very Large Telescope (VLT) in Chile. The object, now called 2M1207b, displayed a spectrum showing water vapor, indicating cool temperatures. This and other measurements hinted the mass of the planet candidate was at most 5 times that of Jupiter, assuming it orbited the brown dwarf. But at the time, astronomers couldn't say for certain that it did.

In August 2004, observations with the Hubble Space Telescope all but clinched the case. Glenn Schneider (University of Arizona) observed 2M1207b with Hubble and, in January, announced that Hubble's position measurements show the object is a true orbiting companion (see News, April 2005).

In February and March 2005, Chauvin's ESO team reimaged 2M1207b. Spanning almost a year's time, the images show no change in the relative position of the giant planet and the young brown dwarf.

"We have observed the objects for a year, and the new images essentially confirm our 2004 finding," says team member Benjamin Zuckerman (UCLA). "I'm more than 99-percent confident." **— MICHAEL E. BAKICH**

NASA/JPL/SSI

**BAKER'S DOZEN. Cassini found a 13th new moon of Saturn in the Keeler Gap May 1, 2005.**

## Scientists find 13 new Saturn moons

Saturn's moon count jumped by 12 on December 12, 2004, when Scott Sheppard and David Jewitt (University of Hawaii) and Jan Kleyna (Cambridge University, England) discovered a dozen new blips inching around the planet.

The closest of the 12 orbits at a distance of 10.5 million miles (16.9 million km). All but one orbit opposite Saturn's rotation.

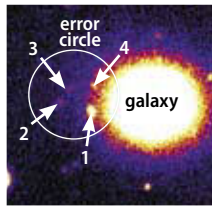
Then, May 1, Cassini caught *another* new moon making waves in the rings. **— RICHARD TALCOTT**

# Short GRB puzzle

A gamma-ray burst (GRB) that erupted May 5, 2005, lasted just 50 milliseconds, but it has left astrophysicists puzzled.

NASA's Swift gamma-ray observatory turned to catch GRB 050509b just 53 seconds after it exploded, and imaged it after another 60 seconds. The GRB left a fast-fading X-ray glow that lasted about 200 seconds. The event is the first time a short-duration GRB has been located.

The brief burst may have signaled the birth of a black hole, perhaps when two older black holes or two neutron stars collided.




KECK/S. B. CENKO

**MYSTERY BLAST. Four possible sources for the GRB lie near a galaxy with old stars.**

GRBs lasting less than 2 seconds have long frustrated astronomers seeking a mechanism, as their brevity yields few observational clues. This burst occurred near an old elliptical galaxy 2.7 billion light-years away.

Astronomers have located four candidate sources and are hoping to see which (if any) was the culprit. **— R. B.**

# Chandra sees stars interacting

Astronomers using the Chandra X-ray Observatory have imaged a pair of interacting stars — Mira A, a supergiant star, and Mira B, a white dwarf.

The group, led by Margarita Karovska (Center for Astrophysics), saw an X-ray burst from Mira A, the first X rays detected from this type of star.

The astronomers also saw a bridge of gas between the two stars. It is likely gas and dust from Mira A is flowing into an accretion disk around Mira B.

The cause of the X-ray burst remains unknown and will need more study to resolve. The Hubble Space Telescope previously observed Mira A and B and determined their angular separation as 0.6", or about 70 AU (where 1 AU is the Earth-Sun distance). **— LIZ KRUESI**

NASA/CXC/SAO

**GO WITH THE FLOW. Chandra has seen gas flowing from the giant star Mira A to the white dwarf Mira B. Its observation is at left, an artist's view at right.**

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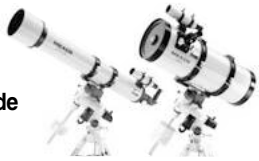

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NASA/CXC/PENN STATE, E. FEIGELSON

**ROUGH-AND-TUMBLE. Powerful X-ray flares in Sun-like stars in the Orion Nebula cluster suggest turbulence in planet-making disks helps rocky planets endure.**

## X-ray super-flares safeguard planets

Powerful X-ray flares from young Sun-like stars may help newborn rocky planets survive their birth, say astronomers using the Chandra X-ray Observatory.

Chandra stared for about 10 days at a rich star cluster in the Orion Nebula. The team observed gigantic X-ray flares erupting from 27 young Sun-like stars. The outbursts are more frequent, and far more powerful, than any from the Sun today.

"We used the cluster as a virtual time machine to view the Sun as it was about 4.5 billion years ago," says team member Scott Wolk (Center for Astrophysics).

Scientists think the super-flares, occurring about once a week per star, would affect any protoplanetary disk around the star. Previous work shows more than half the Orion Nebula's young stars have disks.

A giant flare creates turbulence as the outburst's ionized material sweeps over and through the disk's magnetic fields. The turbulence, says Joan Najita (National Optical Astronomy Observatory), helps keep new planets out of trouble.

"In non-turbulent disks," Najita says, "rocky cores will rapidly spiral into the star," due to the disk's drag. But in a turbulent disk, she explains, "planetary cores can scatter off the fluctuations like small boats tossed about by waves in a storm." **— R. B.**

## Making a space partnership work

NASA/APOLLO-SOYUZ TEST PROJECT

**HANDSHAKE. In 1975, Russian Valery Kubasov (left) met American Tom Stafford in space, and the two nations began a cooperation that continues today.**

This July marked two decadal anniversaries of human space flight breakthroughs. They laid the foundation for today's most critical space challenge: getting the space shuttle flying again to support the International Space Station (ISS).

On July 17, 1975, an American Apollo spacecraft — the last ever launched — docked in space with a Soviet Soyuz spacecraft. This symbolized the end of the space race and opened the way for closer U.S.–Russian cooperation. Then, on July 7, 1995, the space shuttle Atlantis returned to Earth after docking with the Russian Mir space station and picking up the first American to live there.

By then, Russians were already deeply engaged with Americans in building the International Space Station, both as contractors and as full-fledged self-financed partners. Once the first ISS module was launched in late 1998, the project survived repeated setbacks as one side or the other stepped in to make up for the other's problems.

But many promises made for the great space partnership never materialized. Having Russians aboard was meant to make the station faster, cheaper, better, and safer. But in hindsight, none of this happened. (For example, NASA made little use of the Russians' decades of experience with space stations — NASA just learned it all over again on its own).

Tying Moscow's space future to ours was supposed to keep the Russians loyal friends. But the results were ambiguous — and national self-interest usually trumped generous instincts anyway.

Appraising these issues candidly will be important in the next decade, as the shuttle retires, the space station matures, and people venture back out toward the Moon.

NASA astronaut Susan Helms was a member of the station's second expedition crew in early 2001. She pointed out a particular advantage to melding space hardware from two sources.

As a result, she wrote recently, the space station is "essentially two space stations joined together by a hatch, and its overall redundancy by being a 'two-in-one' design has been its saving grace."

Each half "has a significantly different design philosophy, but each one is also capable of many functions that can 'carry' the other one simultaneously."

While the design may look clumsy and inefficient, Helms noted, it provides benefits. "By having such different approaches, each space agency ultimately played to different strengths of their system designs, and in effect, created a larger 'system of systems' that can manage a wide variety of contingencies."

These are the kinds of design and operation strategies that years of experience with ISS are offering space planners around the world.

If properly assessed — if the myths are winnowed from the real lessons — the decades to come should fulfill the space cooperation promises of July 1975 and July 1995 — and perhaps, someday, even July 2005. **— JAMES OBERG**

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LOST AND FOUND. The missing Mars Polar Lander spacecraft may have been found by scientists who compared faint traces at the landing site with similar debris from the Mars rovers. See www.msss.com/mars_images/moc/2005/05/05.

NASA/JPL/ASU IMAGE 20050506A

## White Rock in false color

**NOT WHITE, NOT ROCK. White Rock (left center) is a light feature in Mars' Pollock Crater. Despite the name, given before scientists knew its nature, the feature is fairly soft, gray volcanic ash eroded by wind. This false-color image by the Mars Odyssey THEMIS instrument spans about 16 miles (26 km). It is sunlit from the left.**

GEMINI OBSERVATORY

**PRIZE STAR. RY Tauri is a young star emerging from a dusty gas cloud.**

### Amateurs explore stellar cocoon

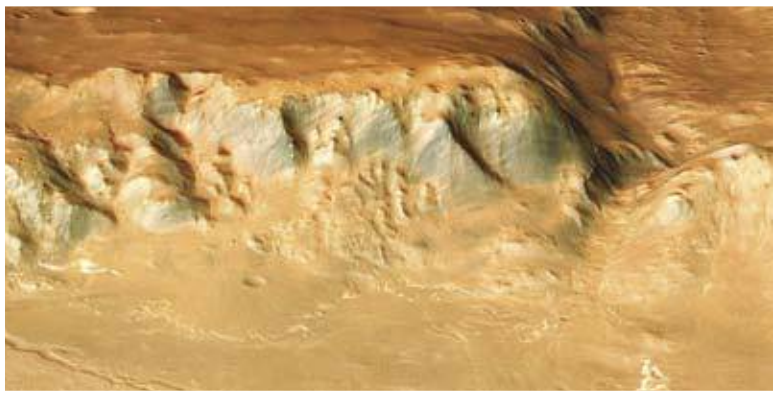
An amateur astronomy club from Montreal used the 8-meter Gemini Telescope on Mauna Kea, Hawaii, to image dust clouds around the young star RY Tauri.

The club's proposal won telescope time in a Canada-wide contest created to honor the role amateurs play in popularizing astronomy.

The star shines much brighter than the wispy material around it, so the observers took many short exposures, stacking them into the final image. **— R. B.**

NASA/JPL/MSSS IMAGE S03-01322

**CREEP OR SLIDE? Rubbly debris has slid out of a small valley (upper left) in Mars' Coloe Fossae. The slide may have been one catastrophic event or a slow creep of ice-rich debris. This MOC image from Mars Global Surveyor, sunlit from the lower left, is about 1.9 miles (3 km) wide.**



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## Where valley meets crater

The now-dry Uzboi Vallis (above right) on Mars flows north, ending where it breaches the southwestern wall of Holden Crater (foreground). Scientists think water flowed in the valley during the Noachian, Mars' oldest geological era. At left, a sloping fan of alluvial debris has washed down from the elevated crater rim.

This image comes from the High Resolution Stereo Camera aboard the Mars Express orbiter. **— R. B.**

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DSLR II shown on a Canon 10D*

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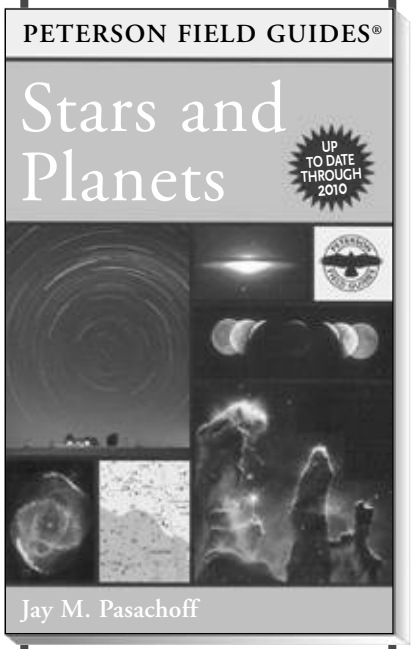


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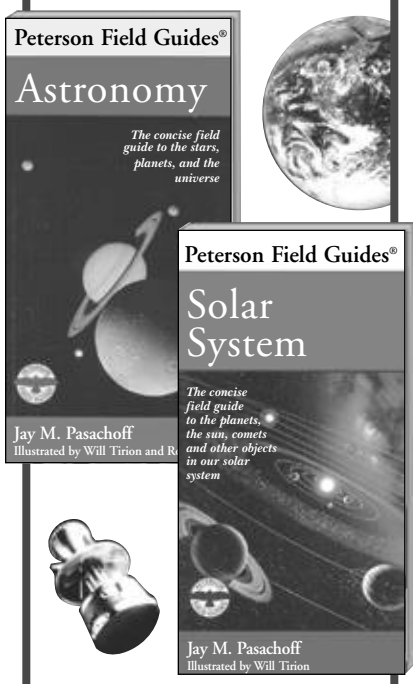
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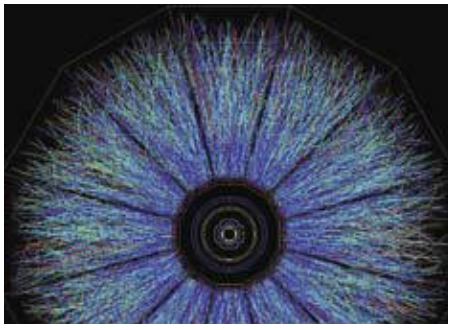
HOT SLOSH. The core of Mars is likely liquid, say scientists studying magnetic effects. Its size, however, is unknown.

# Big Bang in a bottle

Physicists have created evanescent droplets of the fluid that filled the universe microseconds after its birth. By crashing together gold atomic nuclei at 99.995 percent of the speed of light, physicists at Brookhaven National Laboratory in New York have made a new state of matter — a nearly perfect liquid of strongly interacting quarks and gluons, which are the fundamental components of all matter.



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**FAST TRACK. Fleeing subatomic particles leave blue streaks after gold atoms smash at nearly light-speed, recreating the universe as it was 10 microseconds post-Big Bang.**

The researchers believe they've recreated the conditions in the first microsecond of the Big Bang, but they still don't know enough about their quark-gluon liquid, or how it "freezes" into protons and neutrons, to draw cosmological inferences.

Scott Pratt (Michigan State University) explains that if the liquid undergoes a dramatic phase change, like water boiling, "bubbles and drops could grow into seeds for later fluctuations in the universe, such as galaxies." Still, he cautions, preliminary results seem to show a gradual transition.

John Cramer (University of Washington) says the liquid "is telling us that in the first microsecond, the universe was a liquid with a high compressibility." This would tend to damp out any fluctuations, he says, "So it may change the way people try to evolve the universe from the Big Bang into galaxies and stars." **— ROBERT ADLER**

# Magnified quasars confirm Einstein

A new analysis of deep-space images lends the strongest support yet to "cosmic magnification." This phenomenon was predicted by Einstein's general theory of relativity 90 years ago, but is testable only with 21st-century imaging tools and techniques.

Cosmic magnification results from the warping of space-time by matter. One example is gravitational lensing, seen when foreground galaxies make distorted or multiple images of background galaxies or quasars.

Cosmic magnification resembles lensing, but is more difficult to detect. It creates a tiny brightening of distant quasars as their light is bent and focused by intervening galaxies on the way to Earth.

"It's a very small effect, so you have to do this for many, many galaxies and quasars — but it's real," says Ryan Scranton (University of Pittsburgh), a coauthor of the paper on the finding in an upcoming issue of *The Astrophysical Journal*.

The study used thousands of deep-space images from the Sloan Digital Sky Survey showing the position and brightness of hundreds of millions of celestial objects.

Relativity says galaxies will warp space to make distant quasars brighter. So the separation of quasars and galaxies and the quasars' apparent brightnesses should correlate. Which is what the team found: Quasars closest to foreground galaxies are just slightly brighter than average. **— DAN FALK**

NASA/ESA/JHU/ACS SCIENCE TEAM

**BENT LIGHT. Abell 1689, a galaxy cluster 2.2 billion light-years away, "lenses" more-distant galaxies into arcs. This scene spans about 2 million light-years.**

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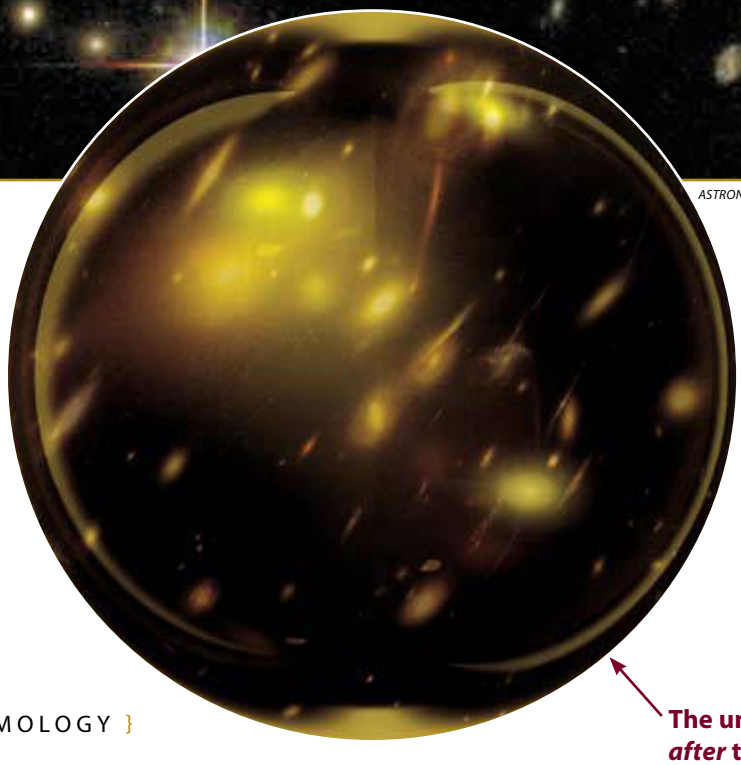


*ASTRONOMY:* ROEN KELLY AND CHUCK BRAASCH

**The universe at actual size, *after* the period of hyper-expansion known as inflation**

{ COSMOLOGY }

# Seeing the dawn of time

Cosmic inflation plugged gaping holes in the Big Bang theory — and turned our universe into one of many. /// BY ADAM FRANK

NASA, HOLLAND FORD (JHU), GARTH ILLINGWORTH (UCO/LICK OBSERVATORY), NARCISO BENITEZ (JHU), MARK CLAMPIN (STScI), GEORGE HARTIG (STScI), THE ACS SCIENCE TEAM, AND ESA

Throughout human history, there are times when a single idea has emerged to bring clarity and sow the seed for further progress. Inflationary cosmology is such an idea. Conceived more than 3 decades ago as an answer to vexing questions that haunted astronomers' attempts to make sense of the universe, it has grown a universe of possibilities all its own.

Like all great ideas, inflationary cosmology is radical. It begins by conceiving the universe in a fetal state — a mere instant after creation and at the edge of our understanding of physical law. Inflation then blows up that universe, driving a brief period of violent expansion that hurtles the cosmos apart at a rate never to be repeated.

From this violent beginning, inflation rescued cosmology from a snake pit of paradox. Uniting astronomy and the hairy edge of particle physics, inflation became a new "standard model" for the universe's birth — an essential component of the Big Bang.

In the 30 years since inflation theory was born, it has gone through its own explosion, opening up newer, more extreme ideas for physicists and astronomers to explore. Far from simply breathing new life into the Big Bang model, inflation has given scientists the confidence to speak of a multiverse — a universe of universes — and even ask the question of our own place in this vastly enlarged cosmos.

## Beginning with a bang

To understand why inflation theory succeeded where other ideas failed, we first have to understand why it was needed at all. It always makes sense to start at the beginning, but the beginning was the very problem cosmologists faced in the 1970s.

**Adam Frank,** *a member of* Astronomy's *editorial advisory board, is a physicist at the University of Rochester in New York.*

By the time the decade of disco and punk rock was well underway, the Big Bang had become the standard model for the history of the universe. Big Bang theory rests on the observation that the universe is expanding. Take this idea and run it backward, and you must conclude the universe was smaller, denser, and hotter in the distant past. The further you rewind the cosmological "movie," the smaller, denser, and hotter the universe gets.

The evidence for this early, super-small, super-compressed, and super-hot cosmic epoch is overwhelming. The most critical support for the Big Bang came with the 1964 discovery of the cosmic microwave background (CMB). That year, radio astronomers Arno Penzias and Robert Wilson began working with a new microwave antenna. A low-level hiss plagued the instrument and, despite their best efforts, they were unable to remove it. The bothersome signal remained, regardless of which direction the microwave "telescope" pointed. At first, they did not know what they had stumbled upon, thinking the hiss was just noise from the electronics.

**Inflation theory began as a bold attempt to solve the problems that plagued cosmologists at the end of the 1970s.**

After tireless work, they concluded the signal was not noise, but a relic of the distant past. The microwaves came from a time when the universe was a hot, dense plasma — a roiling mix of subatomic particles and light. As the universe expanded and cooled, the particles and light waves unmixed, or "decoupled," about 380,000 years after the Big Bang. At that instant, the photons were free to travel unimpeded through space for the rest of cosmic history. Filling every sector of the sky, in every direction, the CMB is a direct link to the Big Bang. Its discovery became a turning point for astronomy — and launched the age of modern cosmology.

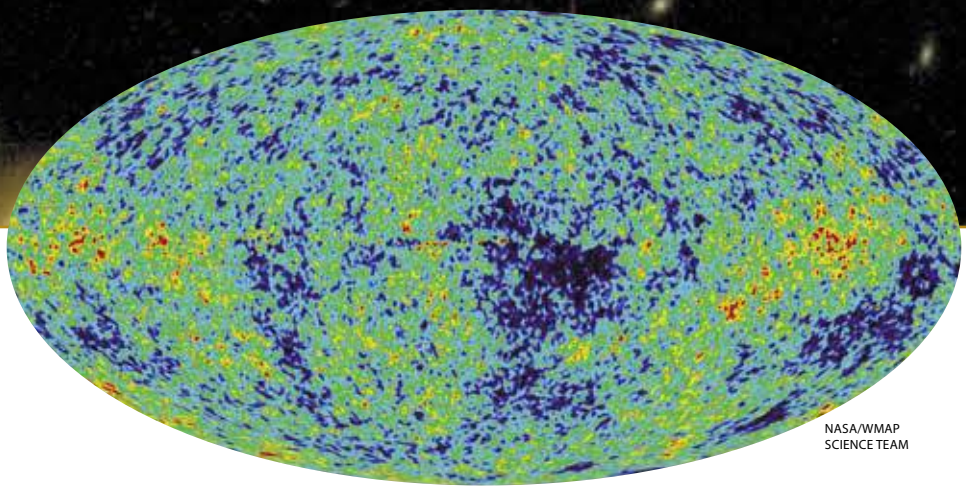
The Big Bang model circa 1975 was a triumph. Researchers actually could say something testable about the young cosmos. But, as observations became more refined and scientists explored the theory in greater detail, troubling dilemmas arose, threatening to topple Big Bang cosmology.

## The three whys of inflation

The difficulties facing the Big Bang model came from several directions. Some emerged purely from observations as astronomers acquired better data. Others emerged from the growing interplay between cosmology and particle physics. By the end of the 1970s, three urgent problems loomed.

**CAUSALITY PROBLEM:** Using the CMB, astronomers could measure the properties of the early universe in different regions of the sky. In particular, they could extract the temperature of the cosmic plasma with great precision.

To their astonishment, they found the temperature remained the same no matter which direction they looked. Even when their instruments pointed in opposite directions, they found the plasma temperature to be the same to one part in 10,000. Why would it be the same everywhere? The universe began as a chaotic, expanding fireball of gas, so it seems reasonable that some parts of the fireball would have ended up with slightly different conditions.



NASA/WMAP SCIENCE TEAM

**THE COSMIC MICROWAVE BACKGROUND is a relic of hot radiation emitted when atoms first formed and light could travel freely, 380,000 years after the Big Bang. The smoothness of this radiation suggests the universe expanded at breakneck speed in the first fraction of a second. (Different colors show temperature differences of a few millionths of a degree.)**

The universe's uniformity on a large scale posed a fundamental problem for astronomers that can be stated simply — cause and effect. "Points on opposite sides of the sky were too far apart when the CMB photons were created," says Sean Carroll, an astrophysicist at the University of Chicago. According to Carroll, regions we now see a hemisphere apart were so distant when the CMB photons decoupled, they could not have had any contact with each other. A light signal could not bridge their separation in the time between the Big Bang and the moment of decoupling. This is the root of the cause-and-effect dilemma.

This means the constant temperatures throughout the universe were an amazing cosmic coincidence. Such coincidences keep astronomers up at night. "If even light didn't have time to make it from one region to the other," says Carroll, "then the different regions couldn't have known about each other. The different regions are too well synchronized [in temperature] to explain with standard Big Bang models." This was the monster problem astronomers and physicists faced in the 1970s. If they could not solve it, their hopes for a rational cosmology might have collapsed.

**FLATNESS PROBLEM:** In cosmology, a single number describes the universe's "shape" and fate. Finding its value is one of cosmology's Holy Grails. Called Omega, it's a measure of the universe's density expressed in terms of a "critical" value. If Omega equals 1, the universe is flat. That means parallel lines will never converge.

If Omega is greater or less than 1, space is curved and, like seams on a beach ball or a western saddle, parallel lines may converge or diverge at cosmic distances. Why is this so important? Einstein, in his general theory of relativity, showed us that the shape of space links to the universe's energy content. The amount of energy also tells us about our eventual cosmic fate — whether the universe will expand forever or one day stop and then start to collapse.

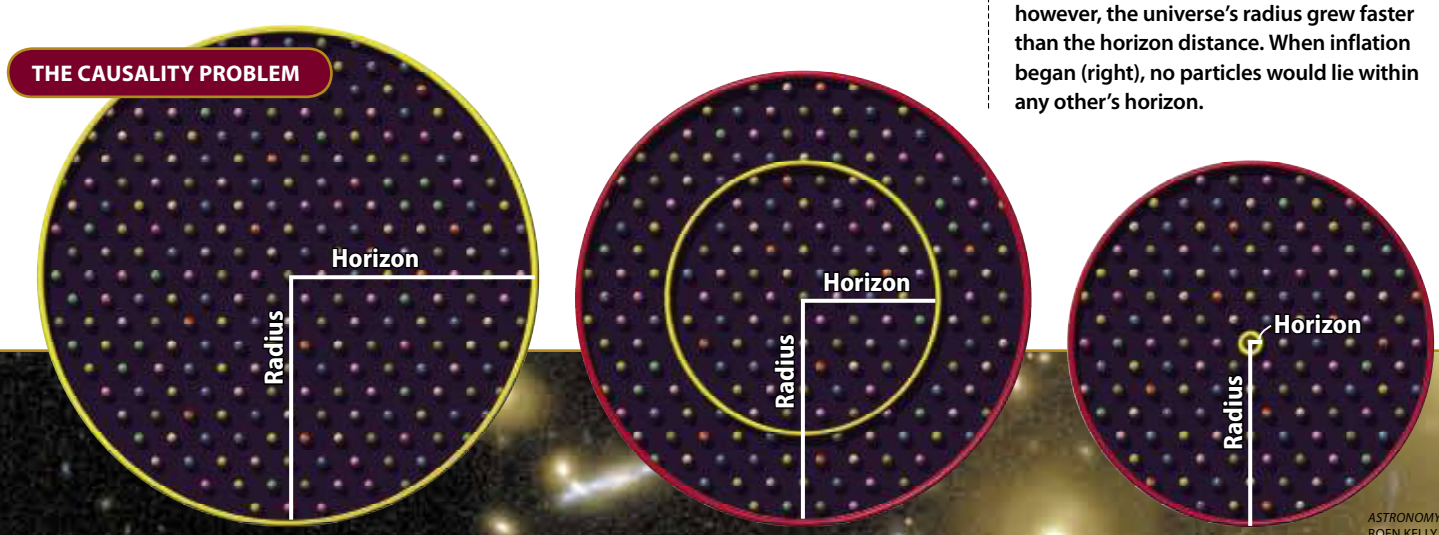
Given its importance, cosmologists have struggled to pin down the value of Omega for years. In all their attempts, the answer comes out close to — but not exactly — 1. That's a real problem.

If Omega equals 1, then it stays so for all cosmic time. If, however, Omega started off greater or less than 1, then the universe's expansion radically changes the value over time, taking it to extremely small or extremely large values. The fact that we now see Omega being close to 1 means something fishy was going on. Either the value was exactly 1 to begin with and we were missing something, or it was tuned to some special value at the Big Bang that just happened to yield Omega almost 1 at this particular moment in cosmic history.

The last alternative asks for a "fine-tuning" of the initial cosmic conditions, and astronomers would not be happy with yet another coincidence. Astrophysicists wanted a theory that naturally leads to Omega equaling 1.

**MAGNETIC MONOPOLE PROBLEM:** Electric charges fill the universe. Some are negative, like electrons, and some are positive, like protons. Physicists call these separate polarities electric monopoles.

**A PARTICLE CAN INTERACT with others only inside its horizon. Today (left), that's everything in the cosmos. At earlier times, however, the universe's radius grew faster than the horizon distance. When inflation began (right), no particles would lie within any other's horizon.**




*ASTRONOMY*: ROEN KELLY

One of the strange things about our universe is that no magnetic monopoles have been seen. Every magnetic field comes with both north and south poles and there are no particles that carry only the north or south "charge." For particle physicists — those who study the fundamental structure of matter — the lack of monopoles seemed weird. In fact, their best efforts to create an all-encompassing model for the nature of matter demanded that magnetic monopoles must have been created during the Big Bang.

Where had all the magnetic monopoles gone? This was the last problem any theory of cosmology had to solve.

"The different regions are too well synchronized [in temperature] to explain with standard Big Bang models." — *Sean Carroll*

## A marriage of two sciences

Inflation theory began as a bold attempt to solve the problems that plagued cosmologists at the end of the 1970s. The basic idea of inflationary cosmology was simultaneously radical and elegant.

With inflation, cosmologists imagined that the part of the universe we can see underwent a brief period of rapid expansion in its early history. "Early" here may be an understatement. Inflation began when the universe was a mere $10^{-34}$ second old. That is less than a million billion, billion, billionth of a second after the Big Bang.

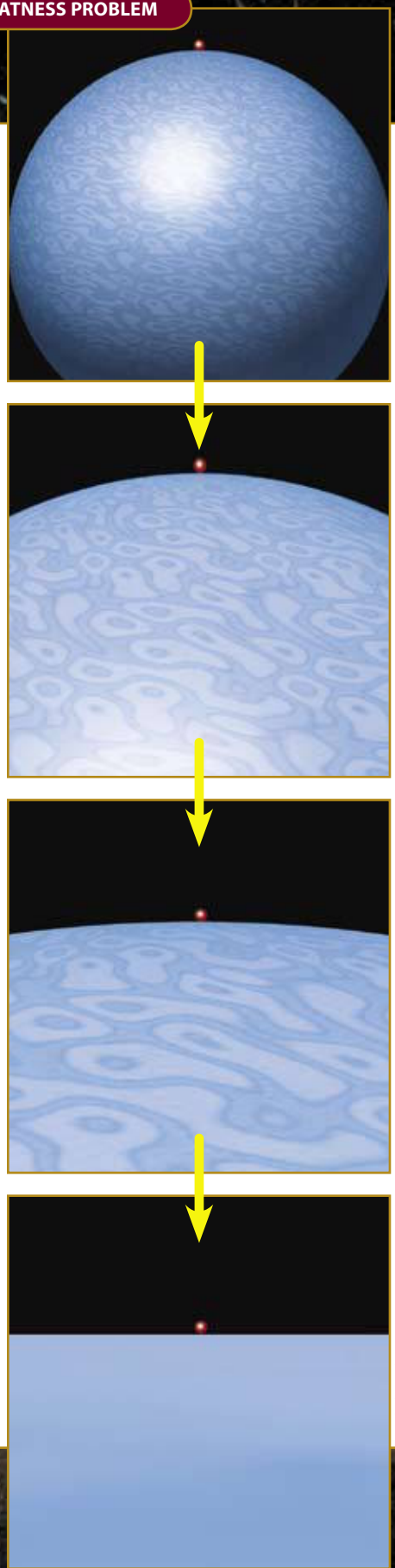
During inflation, the universe expanded by a factor of $10^{43}$ (that's a 1 followed by 43 zeros), increasing from a fraction of the size of a subatomic particle to the size of a softball. This expansion-on-steroids took place in just $10^{-33}$ second. After inflation shut down, the universe resumed the more leisurely expansion we see today. For comparison, in the last half of the universe's life (the past 7 billion years), the scale of the cosmos has increased by a factor of only 10.

While it may seem like a crazy addition to the Big Bang, inflation's brief period of hyper-expansion solved all the problems with standard cosmology. With inflation, the causality problem disappears because every part of the universe we see today *was* in causal contact before everything was stretched to the extreme.

Inflation's expansion solves the flatness problem by pulling space out so flat Omega is forced to a value of 1 no matter what its original value. Physicists were happy to have a theory that didn't require any fine-tuning of the universe's initial conditions.

Finally, inflation does away with the magnetic monopole problem by sweeping monopoles so far away in the period of rapid expansion that the odds of us observing one become essentially zero. With this single change to the Big Bang model, the three big problems were resolved. It was hard for physicists and astronomers not to take notice.

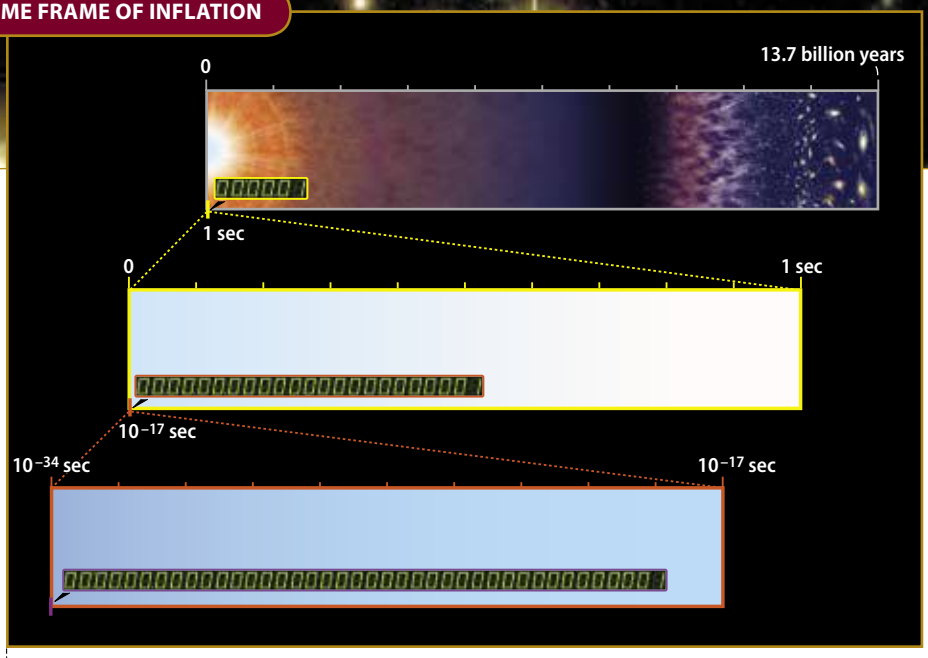
Every good idea needs a champion, and inflation found one in Alan Guth, a physicist at the Massachusetts Institute of Technology. In 1981, Guth wrote a paper describing an inflationary model for cosmology. While some of the ideas had been proposed before, Guth brought them together in a coherent, accessible way and added the catchy name "inflation."




**INFLATION MADE THE UNIVERSE FLAT.** Here, a curved surface expands by a factor of 3 in each panel, appearing nearly flat by the end. To relive cosmic inflation, repeat this expansion 87 more times.

ASTRONOMY: ROEN KELLY

**TIME FRAME OF INFLATION**




ASTRONOMY: ROEN KELLY

**HOW MUCH IS $10^{-34}$ SECOND?** To get an idea, compare 1 second to the 13.7-billion-year age of the universe. Next, divide that 1 second into an equivalent number of parts to get $10^{-17}$ second. Repeat that step one more time, and you'll get back to inflation's beginning.

What mattered most, however, was that Guth was not an astronomer. He was a particle physicist and built his inflation theory using tools from Grand Unification Theories (GUTs).

GUTs have been at the forefront of physics for decades. They are the grand attempt by theoretical physicists to understand the structure of matter and its interactions at the deepest level. There are four known forces in our universe: gravity, electromagnetism, the strong nuclear force, and the weak nuclear force. These are the only ways particles can affect one another.

Particle physicists suspected these forces were different facets of a single "superforce." They predicted if the cosmos could be heated to ever higher energies, each force would sequentially "melt" into the superforce just like ice crystals melt into liquid water.

Of course, the entire universe already had been through a stage when it was as hot as any physicist could ever want. Cosmology gave physicists their laboratory. Guth and those who followed built their inflationary cosmology with ideas taken from GUTs. The critical link between the two was the energy source that drove inflation.

Drawing on GUTs, Guth and others imagined the early universe to be pervaded by a field of energy, a background that mimicked empty space but had energy to burn. They called it the "false vacuum." Extending uniformly throughout space, the false vacuum energy field was unstable like a pencil standing on its point. Sooner or later, the false vacuum had to "decay" into a real vacuum, and the energy in the field would be released.

Inflation was the result of that decay. Kicking in just as the universe cooled to the right temperature, the energy released acted as a kind of anti-gravity force. It repelled space-time itself, providing just the right amount of push for just the right amount of time to inflate a speck of the cosmos into the entire observable universe.

By building inflation from the framework of particle physics and GUTs, Guth and his successors united the realms of the very small with the very large. Inflation has drawn its relevance by bringing cosmology and physics into a coherent whole. This effort continues to bear fruit.

## Meet the multiverse

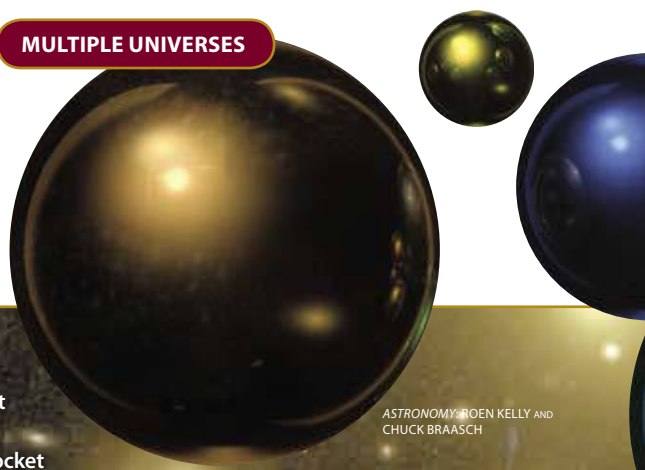
In the years since Guth wrote his first paper, there have been many modifications and variations on the idea of inflation. As Mario Livio of the Space Telescope Science Institute in Baltimore puts it: "Inflation is more of a class of theories than an individual theory."

Much of the newer work has focused on the inflation field itself. In the last 30 years, physicists have explored the various mechanisms that can drive rapid cosmic expansion. Another line of inquiry has looked deeper at the assumptions inherent to inflation. From this work has come a more unorthodox understanding of the very concept of cosmology's subject matter.

The basic idea of inflation is that a speck of the cosmos gets hyper-expanded into the entire observable universe. Even a moment's reflection will tell you there's more cosmos than we can see. What about the rest of it? As physicists and astronomers considered that question, they realized inflation may demand that there be a lot more out there.

"All inflation theories share the same characteristics," says Livio. "They all create a repulsive-gravity phase of the early universe and they grab a speck of space and blow it up by a factor of about $10^{50}$. What they have also done is open up the possibility of eternal inflation." According to Livio, eternal inflation is an idea that raises the stakes on what we think of as the universe.

**MULTIPLE UNIVERSES**



ASTRONOMY: ROEN KELLY AND CHUCK BRAASCH

**EARTH EXISTS** only because the physical laws in our universe are just right. That's a natural result of the multiverse, from which countless pocket universes bubble off from the whole.

Imagine a piece of the universe that is undergoing inflation. Then imagine that only a small portion makes the complete transition from the false vacuum state to the real vacuum state. This "pocket universe," as Livio calls it, will continue to expand at a normal rate and perhaps go on to evolve galaxies and stars and planets and living, thinking creatures.

Meanwhile, all around it is a vast region of space and time still undergoing inflation. Why wouldn't other pieces of this inflating cosmos undergo their own transition to a real vacuum state? "You can end up with a huge ensemble of pocket universes," says Livio.

"All inflation theories . . . grab a speck of space and blow it up by a factor of about $10^{50}$." — *Mario Livio*

This mix of pocket universes surrounded by a still inflating false vacuum is what physicists now call the multiverse, and it requires a dramatic reassessment of the very meaning of the word cosmos. It may also be inescapable.

"Inflation naturally produces a multiverse," says Livio. "If you believe in some form of inflation, then it is almost inevitable that some form of eternal inflation will occur."

## Our mediocre universe

If all those extra pocket universes exist, it would seem physicists have a lot more to study. The multiverse, however, is not so transparent. "The different universes would not be causally connected," explains Livio. No signals from one pocket universe could ever reach another. That means there is no way to study them. In spite of this cosmic barrier, there may be ways to tell something about the multiverse just by looking at our little pocket of reality.

Physicists have long known the nature of physical laws in our universe may be an accident. Just as ice crystals form in a seemingly random pattern, the exact way our forces froze out of the superforce could have been different if cosmic history were run again. Gravity might have been stronger or weaker, for example.

Changing something like the force of gravity or electromagnetism even slightly alters all cosmic history with respect to the creation of life. Weaker gravity means stars never form, and that means no life. Stronger electromagnetism means biomolecules can't form, and that means no life.

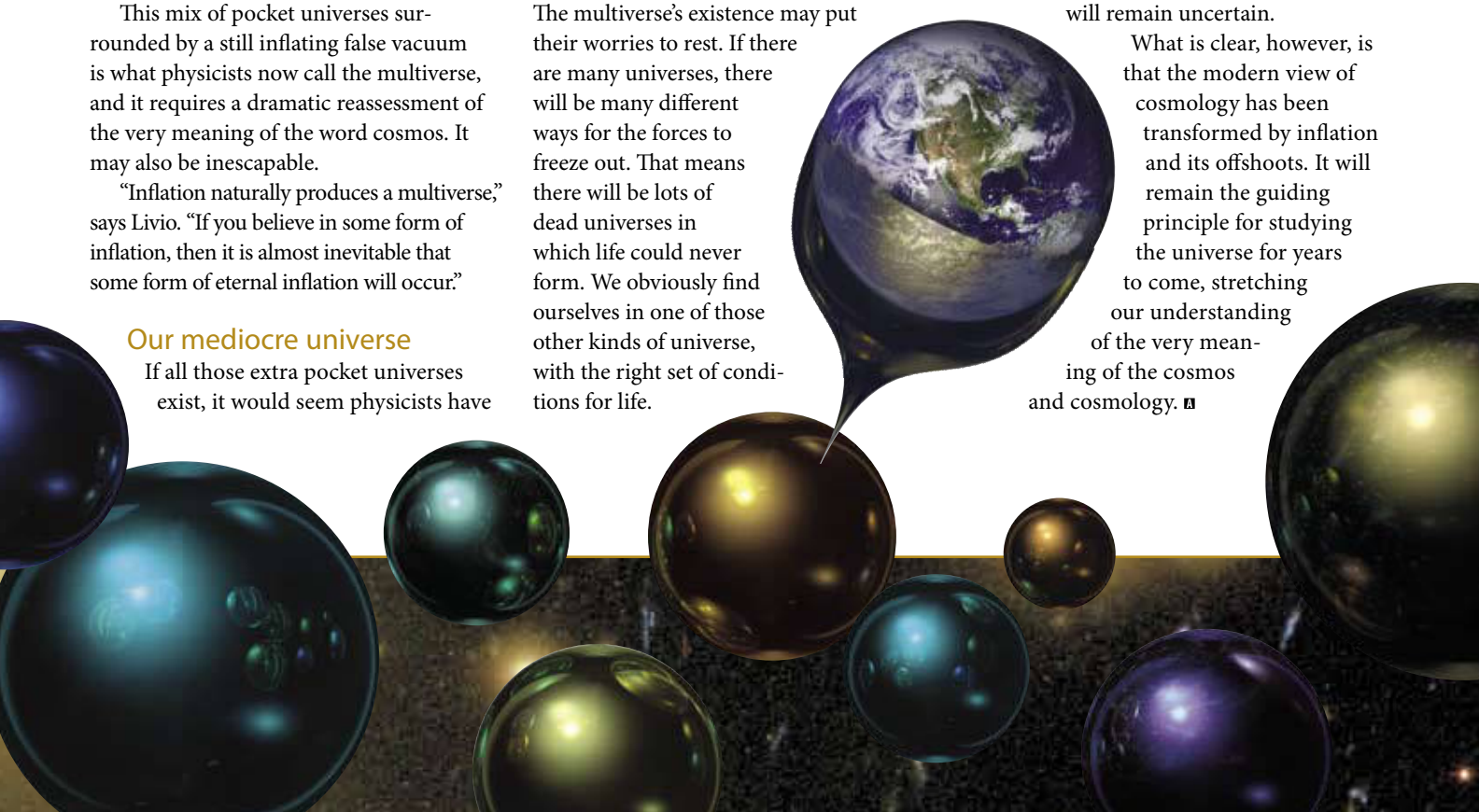
As you might expect, this apparent fine-tuning of physical laws to allow life has bothered some physicists for many years. The multiverse's existence may put their worries to rest. If there are many universes, there will be many different ways for the forces to freeze out. That means there will be lots of dead universes in which life could never form. We obviously find ourselves in one of those other kinds of universe, with the right set of conditions for life.

Some researchers have taken this reasoning even further, arguing that because we wouldn't expect to end up in a "special" universe (that would be more fine-tuning), our conditions must be similar to those that any randomly chosen universe would end up with. That means one can use our existence to say something about the statistics of pocket universes in the multiverse. As you might imagine, this idea — like the existence of the multiverse itself — is a hotly debated point.

From the false vacuum to the multiverse, inflation has transformed the way scientists view cosmic history and the stuff of cosmology. What began as a radical solution to a suite of paradoxes has grown into an ever-expanding paradigm for viewing what is and what can be.

For all its successes, however, inflationary cosmology remains a theory. Because it deals with such small distances, early cosmic times, and high energies, it lies beyond the reach of laboratory study. Although it is consistent with all current cosmological observations, there has yet to be a direct test of its predictions. Thus, its fate and the fate of all the universes it seems to predict will remain uncertain.

What is clear, however, is that the modern view of cosmology has been transformed by inflation and its offshoots. It will remain the guiding principle for studying the universe for years to come, stretching our understanding of the very meaning of the cosmos and cosmology.



# Postcards from Mars

Messages from two lonely rovers show the Red Planet is wetter, dustier, and much more complex than anyone imagined. /// BY MICHAEL CARROLL

Before the Mars Exploration Rovers (MERs) Spirit and Opportunity landed in January 2004, the idea of a mobile mission lasting more than a year on Mars seemed a long shot.

NASA's last attempt to land on Mars — the ill-fated Mars Polar Lander — vanished without a trace on arrival in December 1999. And the European lander Beagle 2 failed similarly, just prior to the rovers' own landings, in a sharp reminder of how treacherous landing on Mars is.

The odds of success looked poor. The rovers would need to fire hundreds of pyrotechnic devices; deploy parachutes and airbags; and swivel, extend, or jettison various shells, covers, and instruments for their missions even to begin.

But NASA's twin rovers not only survived their jouncing arrival, they have thrived in the martian surroundings far beyond their projected life expectancies. What they found has transformed humankind's view of Mars, past and present.

## Change the world

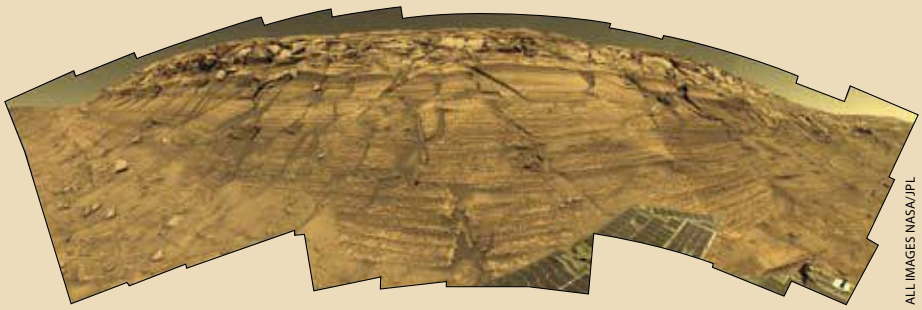
When the canal-laced Mars of Percival Lowell abruptly gave way in the 1960s to the cratered landscapes of the first Mariner flybys, scientists and the public alike developed a view of Mars as dead and Moon-like. But that view was eroded gradually by a host of orbiters and three successful landers — Vikings 1 and 2 (1976) and Mars Pathfinder (1997).

Orbital images and mineralogical studies from the surface and from orbit now hint at a Mars whose past was much wetter than thought previously. How much water ponded into surface lakes or oceans is still debated, yet the question of indigenous martian life continues to drive most of Mars exploration.

NASA's overarching approach to Mars — one that the rovers fit into well — is, simply stated, "Follow the water."

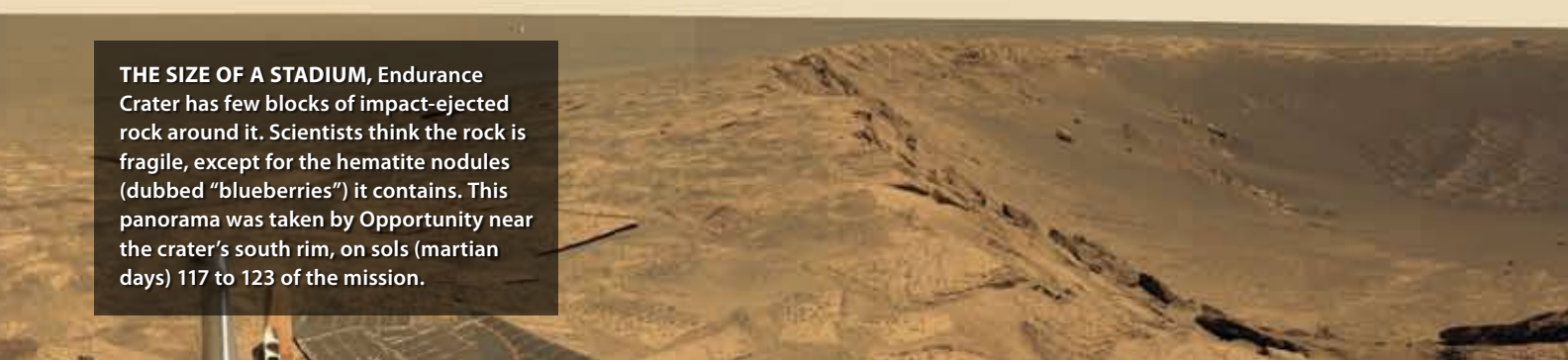
NASA's chief scientist (and longtime Mars scientist) James Garvin explains where this philosophy comes from. "If we follow the path of the water, we can understand the history of the rocks, the climate, and past or present life. We're looking for preservation environments, areas that might preserve these records."

Garvin and others believe this is the best approach for discovering key secrets to Mars' geological development, and — if life ever arose — to its biological development as well. "We're looking for water on the rocks," Garvin quips, "and the strategy came to a head in MER."

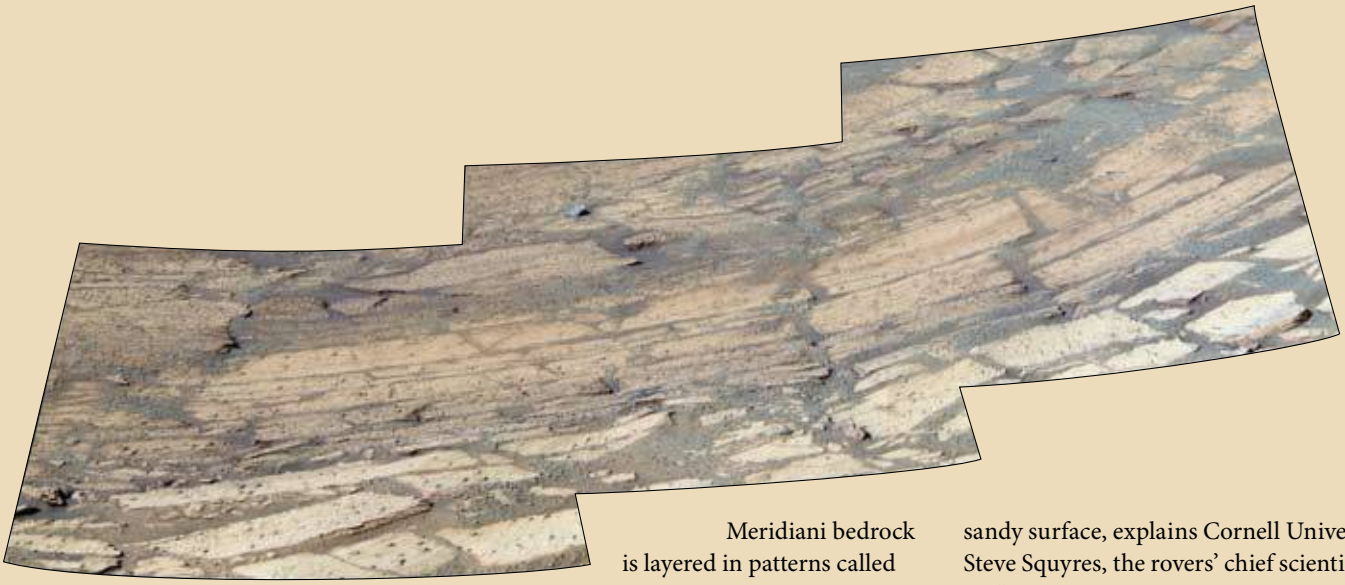


ALL IMAGES NASA/JPL

**LOOKING LIKE A WALL,** Burns Cliff stands about 6 feet high and forms part of Endurance Crater's southeast rim. Scientists have mapped three broad rock units in the cliff, all with indications of having been deposited in water. The perspective in this wide-angle image makes the cliff bulge toward the camera; in reality, its surface curves gently.



**THE SIZE OF A STADIUM,** Endurance Crater has few blocks of impact-ejected rock around it. Scientists think the rock is fragile, except for the hematite nodules (dubbed "blueberries") it contains. This panorama was taken by Opportunity near the crater's south rim, on sols (martian days) 117 to 123 of the mission.



**ROCKS UNDERFOOT in Endurance have several common characteristics, including lots of sulfate minerals. But when studied closely by Opportunity, the lower layers (which lie farthest from the camera in this false-color image) showed signs of having blown around as dunes before being cemented into rock.**

The tactic guided the choice of landing sites for Spirit and Opportunity. Spirit's touchdown site in the Connecticut-size crater Gusev targeted an area that appeared, pre-landing, to be covered in lake deposits from an ancient river that breached the crater's rim. Opportunity set down in Meridiani Planum, a flat plain covered with the iron-oxide mineral hematite, which often forms in water-rich environments.

Of the two rovers, scientists were surprised to find that Opportunity, although it landed 3 weeks after Spirit, still hit paydirt first.

## Opportunity: first results

As soon as Opportunity began taking images, its cameras spotted the Holy Grail of geology: bedrock. Bedrock is rock-in-place, rock lying where it formed. Bedrock can tell you what happened in that spot because it records geohistory in layers organized chronologically. In this case, the Meridiani bedrock is layered in patterns called crossbedding. This shows as thin strata in the rocks that interweave and cut across one another.

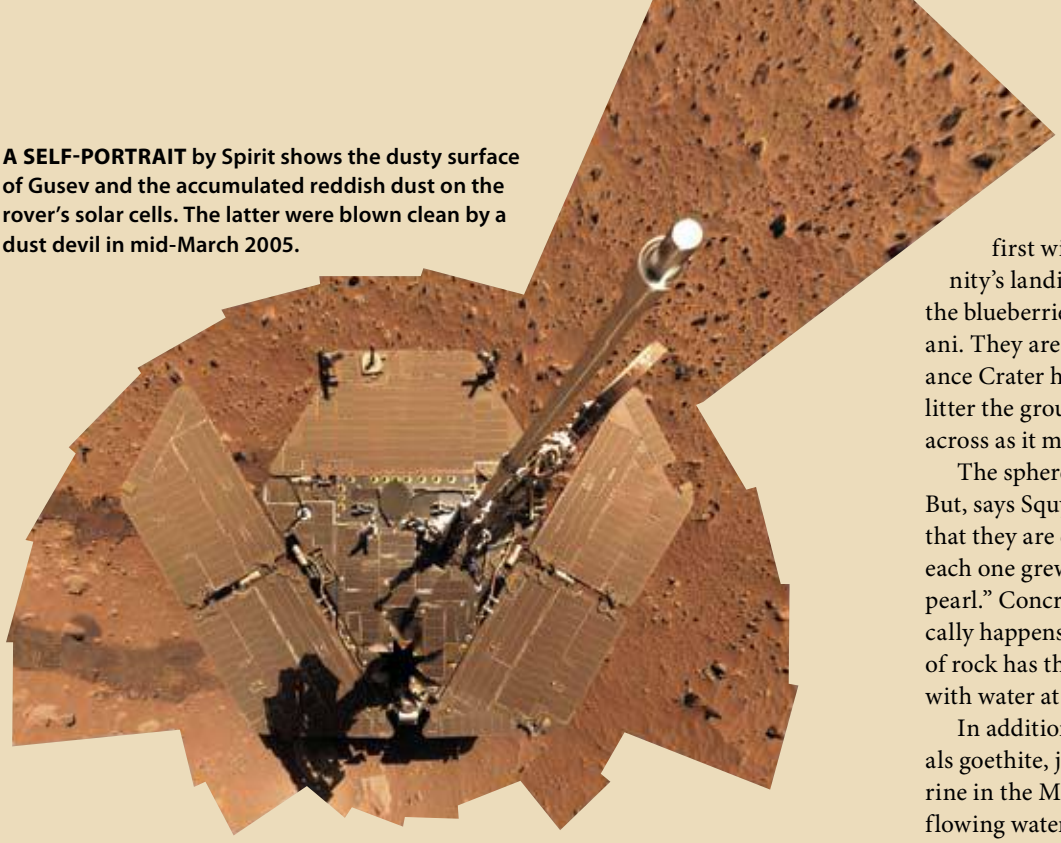
Either wind or water can create crossbedding, but Opportunity's Microscopic Imager (MI) found other indicators pointing to water. The Meridiani rocks contain vugs, randomly oriented hollows about half an inch long. These distinctive features mark sites where crystals of salty minerals congregated in the rocks when they were soaked in briny water. As the crystals dissolved, they left vugs behind.

A third indicator of water, first glimpsed from orbit by the Mars Global Surveyor (MGS), is the presence of hematite. Before Opportunity landed, and during its first sols, scientists were unsure exactly where all the hematite was. It turned out that the hematite lies within spheres a few millimeters in diameter that the scientists dubbed "blueberries." They lie embedded in the rock outcrops and have eroded out onto the sandy surface, explains Cornell University's Steve Squyres, the rovers' chief scientist.

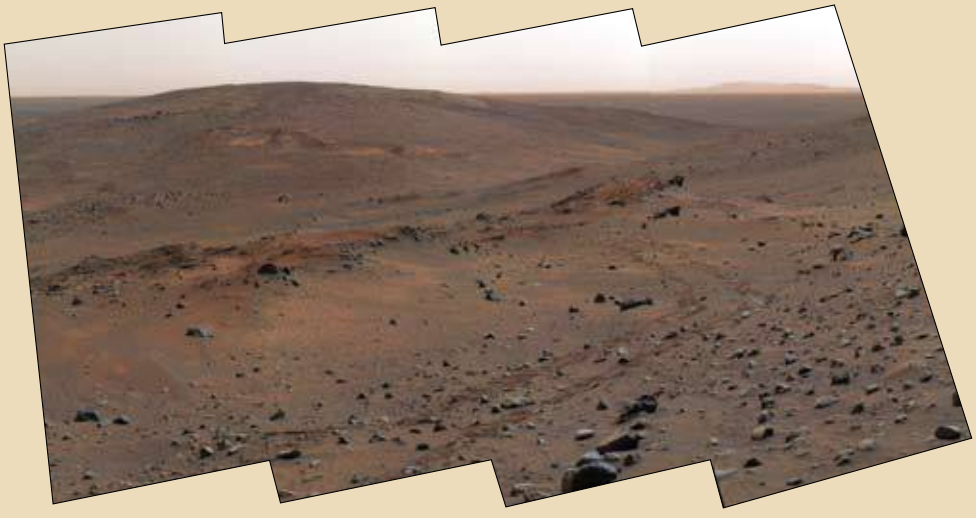
"The blueberries are stronger than the muffin," he says, "so they erode from the bedrock. These things are not coarse-

**WAVY LINES in this rock are called crossbedding and indicate the rock was deposited either as dunes or under shallow and turbulent water. The spheres are the hematite-rich blueberries.**

**THE INSIDE VIEW shows Endurance as a bowl with rocks half buried by sand and windblown dust, which has pooled in dunes in the crater bottom. In the foreground the rocks lie like paving blocks and are covered with a nearly continuous carpet of blueberries.**



**A SELF-PORTRAIT** by Spirit shows the dusty surface of Gusev and the accumulated reddish dust on the rover's solar cells. The latter were blown clean by a dust devil in mid-March 2005.



**LAYERED ROCKS** at a Gusev Crater outcrop dubbed Methuselah are rich in titanium and phosphorus like many rocks on the hillside. Spirit is finding rock outcrops with varying chemical histories, suggesting the Columbia Hills are a geological melange.

grained, so they're very hard. It's like digging into cottage cheese with marbles."

Scientists studied blueberries first within Eagle Crater, Opportunity's landing site, but they soon found the blueberries are ubiquitous at Meridiani. They are just as prevalent in Endurance Crater half a mile away, and they litter the ground Opportunity is driving across as it motors southward.

The spheres could be volcanic in origin. But, says Squyres, "There's good evidence that they are concretions, meaning that each one grew like an oyster building a pearl." Concretion is a process that typically happens in water. "Every single piece of rock has them. The place was saturated with water at some point," says Squyres.

In addition, the presence of the minerals goethite, jarosite, bromine, and chlorine in the Meridiani rocks point to flowing water in Mars' past. "What's exciting is the chemical stuff, the stuff formed by water," Squyres says.

Researchers acknowledge the water may have percolated through rock beneath the surface of a dry Mars. But the likelier, and more intriguing, possibility is that water may have once lapped against the shores of Meridiani.

## Endurance Crater

After spending its first 8 weeks in tiny Eagle Crater, Opportunity ventured east to stadium-size Endurance Crater. There, after scouting the interior slopes carefully from the rim, the rover nosed over and drove down the inside wall.

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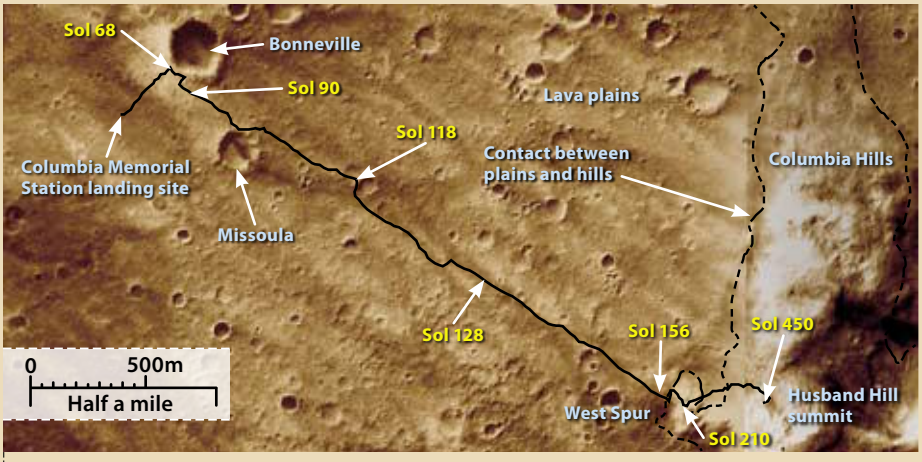
*When* **Michael Carroll** *isn't painting Mars scenes (and other places in space), he's writing about his favorite neighbor, the Red Planet.*

**IN THE COLUMBIA HILLS,** Mars rover Spirit has found rocks that show strong signs of water's touch — unlike those down on the plains of Gusev Crater, which are wholly volcanic basalt with few signs of water. Because the hills appear to contain rocks from several sources (and, probably, ages), scientists hope to discover samples from earlier martian history.




**IT'S BEEN A LONG ROAD.** Miles from where it landed, Spirit is now high in the Columbia Hills, mapping the geology and searching for rock layers showing the effects of water.

Scrutinizing rocks on the way down, Opportunity profiled a layered history in stone going back much further in time. The rocks at Endurance's rim seem to match those at Eagle and are just as riddled with salty minerals. But as the rover explored deeper, the sulfate levels in the rocks started to decline.

Says rover science team member Benton Clark of Lockheed-Martin, "There's quite a gradation." One of two things may have happened, he explains. "First, the salts may have come from above, so there's more in the upper layers. Second, ground water may have wicked up to the surface and drawn salts with it."

If the Opportunity site did constitute beachfront property, it was long ago. Meridiani is thought to be ancient, lying in the earliest preserved, or Noachian, terrain. Says Clark, "It couldn't have rained since crater formation at Meridiani, or you'd wash out the upper layer [of salts], and it would end up below."

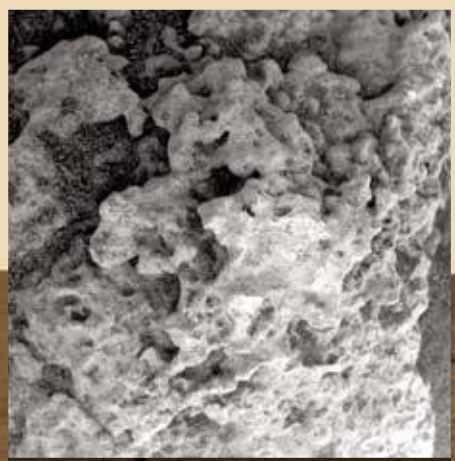
How wet is it now? "My calculations indicate the amount of water may be 6 to 18 percent." This water is combined chemically with minerals in the rock and soil.

Opportunity's remarkable luck continued with the discovery of a rock dubbed Bounce (because the rover's airbag struck it when Opportunity bounced in for its landing). Bounce is similar chemically to the martian meteorites found on Earth — and it's unlike the bedrock seen at Meridiani. Scientists therefore think it's a piece of ejecta from an unknown, distant crater.

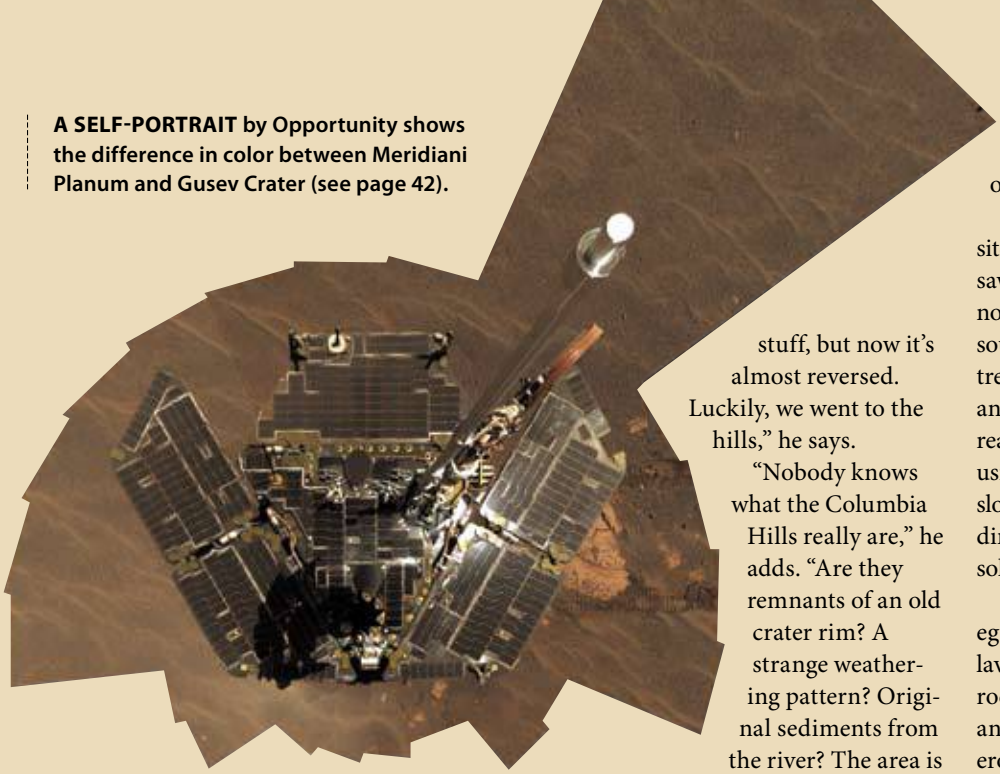
In January 2005, after successfully driving up and out of Endurance, Opportunity examined a rock lying near where the rover's heat shield landed. The rock was called Heat Shield at first, then renamed SpongeBob. Clark says, "When we looked at this thing with the Mini-TES [spectrometer], it looked like the sky." Such spectral behavior is characteristic of what a metal object would do. The alpha particle X-ray and Mössbauer spectrometers on the rover's instrument arm soon revealed the basketball-size rock is made of nickel and iron. It's a meteorite, the first discovered on another world.

**PASO ROBLES,** being studied by Spirit's instrument arm, is a patch of soil that's rich in phosphorus and half iron-sulfate salt. Its chemistry points to a wet origin.

**FALSE COLORS** show the soil composition at Paso Robles: Redder is richer in iron, while white and bluish-white indicate patches rich in sulfur.



**UNDER THE MICROSCOPE,** a piece of cohesive soil or extremely soft rock reveals weathering details that suggest possible erosion by water.



**A SELF-PORTRAIT** by Opportunity shows the difference in color between Meridiani Planum and Gusev Crater (see page 42).

## Spirit: heading for the hills

While Opportunity quickly racked up evidence for a wetter ancient Mars, on the other side of the planet, Spirit's results were less conclusive, at least at first.

In the beginning, says Squyres, the Meridiani site was the star of the MER show. "Gusev just made us work a lot harder for it, but at Gusev are the coolest rocks we've yet found." Clark agrees. "Meridiani started out with all the good stuff, but now it's almost reversed. Luckily, we went to the hills," he says.

"Nobody knows what the Columbia Hills really are," he adds. "Are they remnants of an old crater rim? A strange weathering pattern? Original sediments from the river? The area is topographically challenging, but it's a treasure. I'm flabbergasted by the diversity of unusual rocks at Gusev."

One basaltic rock found early in the mission was called Humphrey, a dark volcanic specimen about 2 feet tall. Within the rock, bright cracks contain minerals that likely crystallized from water. The water may have been mixed into the original magma that formed Humphrey, or it may have flowed through the rock later, after it hardened. But basalt, the most common volcanic rock in the solar system, is not promising material for a mission bent on finding water's traces.

After scientists found Spirit's landing site was surrounded by basaltic rocks and saw that nearby Bonneville Crater exposed no sedimentary rocks either, they looked southeast and sent Spirit on a months-long trek across 2 miles (3 kilometers) of sand and rocks to the Columbia Hills. Upon reaching them, Spirit began a slow ascent, using the hills' north-tilting (Sun-facing) slopes to augment the spacecraft's power, diminished by dust accumulating on its solar panels.

"Head for the hills" proved a wise strategy because as soon as Spirit drove off the lava plain, it promptly found an unusual rock dubbed Pot of Gold. This rock, plus another close by, proved to have been eroded internally — hollowed-out perhaps by wind or water or both.

Not far away lay Wishstone, another unusual specimen. A nearby rock dubbed Wishbone turned out to be inaccessible, so Wishstone was chosen as an alternate target, with researchers "wishing" it would turn out to be just as valuable. It did.

Wishstone exhibits features pointing to an explosive origin, presumably a meteor impact or volcanic event. Wishstone and a second rock called Wishing Well are richer in phosphorus than any rocks yet seen on

**OPPORTUNITY'S HEAT SHIELD** (left) hit the ground at high speed, making a shallow crater, and snapped inside-out, scattering pieces at center. In the crater, the reddish material is disturbed soil; the darker streaks may be charred bits of the heat shield.

**WIND AND SAND** are working to eradicate Viking Crater (right) on the plains of Meridiani in this panorama. Viking is about 30 feet (9 meters) wide and is surrounded by small blocks of ejecta. Opportunity passed the crater on sol 421 of its mission.

Mars. This mineral can be formed in the presence or absence of water, so scientists are seeking further evidence to understand the histories of these samples.

But an outcrop called Peace proved outstanding. "Peace is really hot news," says Clark. "It's wholly different from other rocks we've analyzed, truly bizarre."

Squyres agrees. "Peace may be the most important and exciting thing we've found with Spirit. It took us 4 kilometers and a year of driving, but it's the most compelling evidence for water on Husband Hill."

Peace and an adjacent site called Alligator seem to be part of the bedrock making up Husband Hill, one of the Columbia Hills.

The outcrop consists of basalt grains different from any basalt seen yet. The grains are cemented together by magnesium sulfate, which makes up a full 20 percent of the sample, according to Squyres. "It's a water-related process different from Meridiani. This stuff isn't subtle. It's in your face."

A little later at a place called Paso Robles, Spirit's wheels churned the soil, leading initially to worries it might get stuck. Then the scientists looked more closely at the camera images. They showed bright soil underneath the topmost layer that turned out to be more than half salt, again pointing to materials that formed in water or by its action. But how the water got there remains unknown.

**IN A SURPRISE,** Opportunity discovered a meteorite, the first found on another planet. The basketball-size object is mostly nickel-iron. Scientists are unsure how long it has been on Mars, but it appears barely weathered.

## CSI: Mars

Spirit and Opportunity have peeled away another layer of the onion that is Mars — Garvin describes the rover investigations as "*CSI* does Mars."

While the rovers were born under the umbrella of NASA's Follow the Water plan, Clark sees a shift in research coming.

"The strategy of following the water," he says, "was, I think, a good one. It tells us about different climates Mars has had. Did it have rainfall? Is life a possibility, past or present?" But the next step, he advises, "will be to follow the carbon."

Carbonate minerals set limits on the extent of the ancient martian atmosphere and how warm the planet was. And if carbon is important to possible life in the martian past, it may also be important to future human visitors. The carbon in carbon dioxide can combine with hydrogen (split from water) to make methanol for vehicles, and methane for rocket propellant. On-site manufacture of fuels from martian resources is critical to most scenarios for human Mars exploration.

Garvin adds that "the best indicator of life is reduced carbon. This may be preserved in sulfates, so some researchers, like Mike Malin, who built the camera system on MGS, suggest following the sulfates."

What's in store for the robot explorers? Spirit continues to venture higher into the Columbia Hills, where, according to Clark, the finds "just keep getting better and better." After the summit of Husband Hill — and a breathtaking panoramic view of Gusev — the rover may head for a basin on the hills' east side where sediments may collect. But everything, of course, depends on Spirit's continued good health.

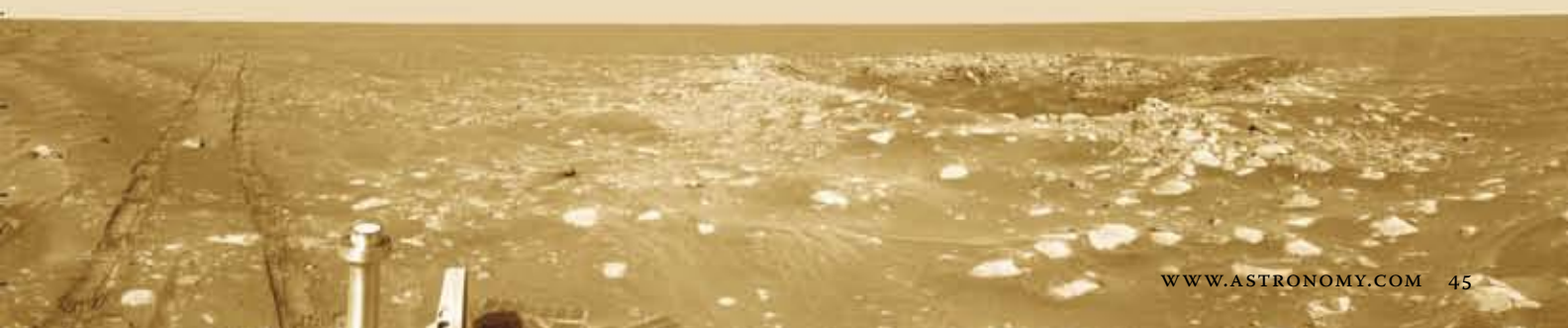
Freed from a clingy sand dune, Opportunity is driving south, threading its way into an area called the Etched Terrain. Scientists are unsure whether the rocks exposed there lie above or below those they've already explored at Endurance.

Beyond lies Victoria Crater, 5 times wider and deeper than Endurance. Can Opportunity find a route in? If it enters, can it get out again? And after Victoria, what should be its next destination? Mission scientists, living mostly day-to-day, have hardly looked that far ahead.

Eventually, both rovers will die. Yet wonderful surprises surely await us in the new martian neighborhoods they're exploring. If the rovers' mission so far is any guide, great things still lie ahead.

**OPPORTUNITY'S ROUTE** has taken it far since it landed in Eagle Crater, more than 450 sols ago. The Meridiani plains have proven easy to drive on, being flat and relatively obstacle-free.

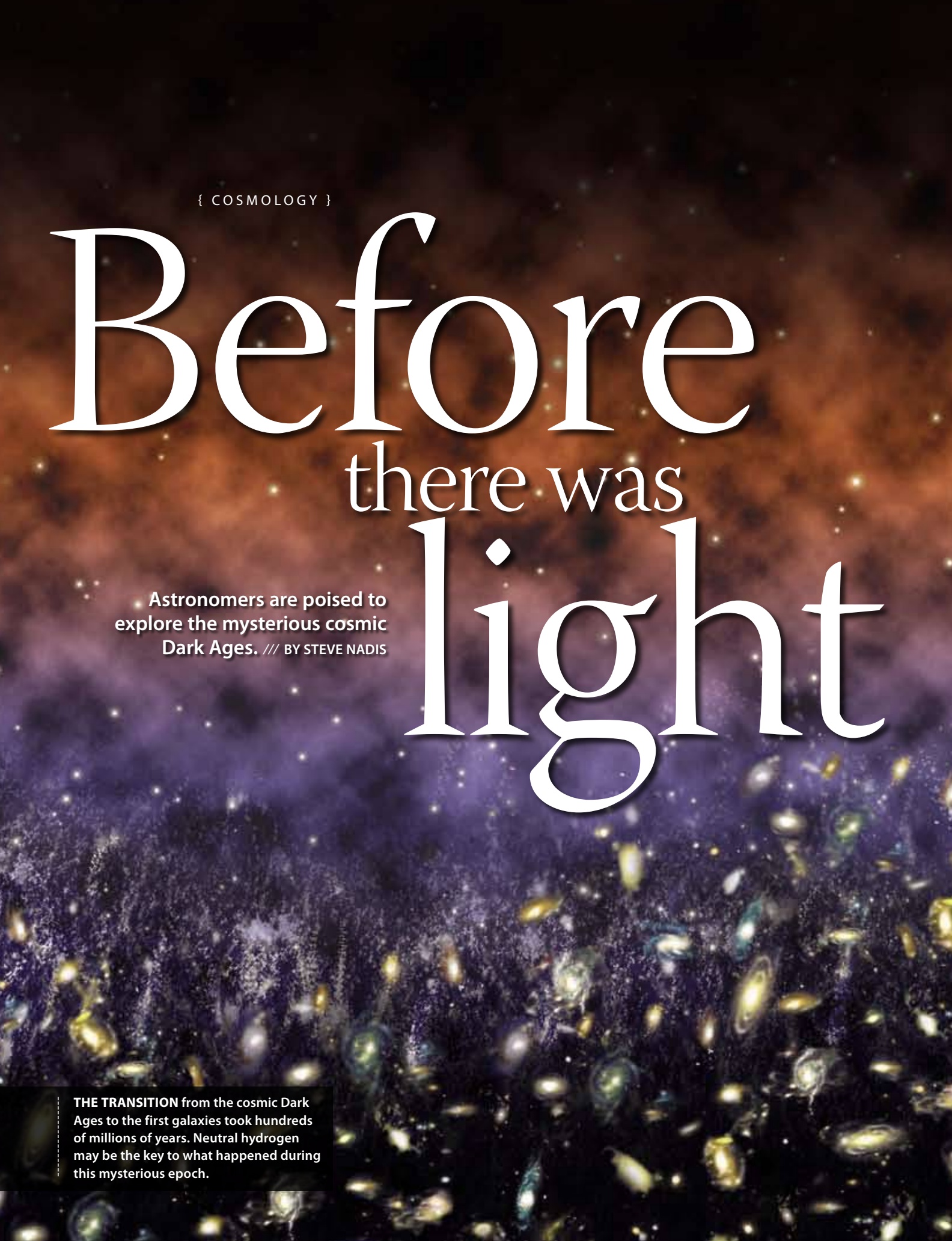
**ONLINE EXTRA** To see how the rovers may fail, and how engineers work to forestall this, go to www.astronomy.com/toc



{ COSMOLOGY }

# Before there was light

**Astronomers are poised to explore the mysterious cosmic Dark Ages.** /// BY STEVE NADIS



**THE TRANSITION** from the cosmic Dark Ages to the first galaxies took hundreds of millions of years. Neutral hydrogen may be the key to what happened during this mysterious epoch.

Cold dark matter models of Big Bang cosmology predict the emergence of structure during the "Dark Ages" — the period after the Big Bang's heat was unleashed and before the first luminous sources turned on — but direct evidence is hard to come by.

Dark matter is invisible, by definition, having eluded detection efforts. However, the most abundant element of "ordinary matter," hydrogen, has a convenient observational signature. To astronomers hoping to probe this cosmic dark era, neutral hydrogen's 21-centimeter line may be all they have.

A neutral hydrogen atom consists of one proton and one electron. The electron's direction of "spin" — spin is an intrinsic property of particles — can be either aligned with or opposed to that of the proton. The atom has slightly greater energy if the spins are aligned. Because of this, when the electron flips its spin from aligned to opposed — from a higher to a lower energy state — it emits energy in the form of a photon with a wavelength of 21 centimeters [see "At the atomic level," page 48].

"That's why everyone is so excited about hydrogen's 21-centimeter line," says Ger de Bruyn of ASTRON, the Netherlands Foundation for Research in Astronomy.

## So where's the signal?

Radio telescopes will be used to track primordial hydrogen because any 21cm radiation from early epochs has been stretched to meters-long radio waves by the universe's expansion. Because of this, the new telescopes will look at wavelengths between 1.5 and 5.3 meters. Snaring these long-wavelength, low-frequency signals, says Harvard theorist Lars Hernquist, "is the next big frontier in observational cosmology" — a sentiment shared by the people behind the telescopes.

Indeed, there is a ferment of activity in radio astronomy these days, as researchers prepare to hunt for the "cosmic hydrogen background." Prototypes have already been built for several radio surveys: the LOw-Frequency ARray (LOFAR) in the Netherlands; the PrimevAl Structure Telescope (PAST) in China; and the Mileura Widefield Array (MWA) in Australia. "This is not just a few experiments," notes Massachusetts Institute of Technology (MIT) astrophysicist Miguel Morales. "It's the birth of a field."

Jeff Peterson, a Carnegie Mellon physicist co-leading PAST with Xiang-Ping Wu of China's National Astronomical Observatory, is looking forward to practicing astronomy at redshift 17, some 200 million years after the Big Bang. "We have quasar astronomy at redshift 6 — a billion years after the Big Bang — and cosmic microwave background [CMB] astronomy at redshift 1,000 — a few hundred thousand years after the Big Bang — but nothing in between," he says. "Here's a chance to see 5 times farther than Hubble or Sloan [Digital Sky Survey] — a chance to advance astronomy fivefold."

> "This is not just a few experiments. It's the birth of a field." — *Miguel Morales, Massachusetts Institute of Technology*

Astronomers hope to figure out where neutral hydrogen has accumulated over time and when it reverted to its ionized form. After the Big Bang, all gas was hot and ionized. The universe cooled as it expanded, and hydrogen became neutral, with its constituent protons and electrons joining together as neutral hydrogen at the moment of recombination. The CMB followed shortly afterward.

Neutral gas in the intergalactic medium reionized hundreds of millions of years later — the exact time is still to be determined — when it was heated by radiation from early stars, galaxies, and quasars. The universe went from ionized to neutral and back to ionized.

The latter phase, called reionization, may be discernible as a bump in the sky's radio background. "Our best chance of detecting the reionization signal is if the neutral gas disappeared quickly," explains Steve Furlanetto of the California Institute of Technology. If the change occurred gradually, it will be harder to pick out amid the background noise of the Milky Way and other galaxies.

If astronomers can determine the frequency of the "bump" in the radio spectrum when the neutral gas abruptly vanished, they'll immediately know the redshift, which will tell them when reionization happened. Next, they'll look for how it happened: In other words, what sources lit up the universe?

## Zooming in on reionization

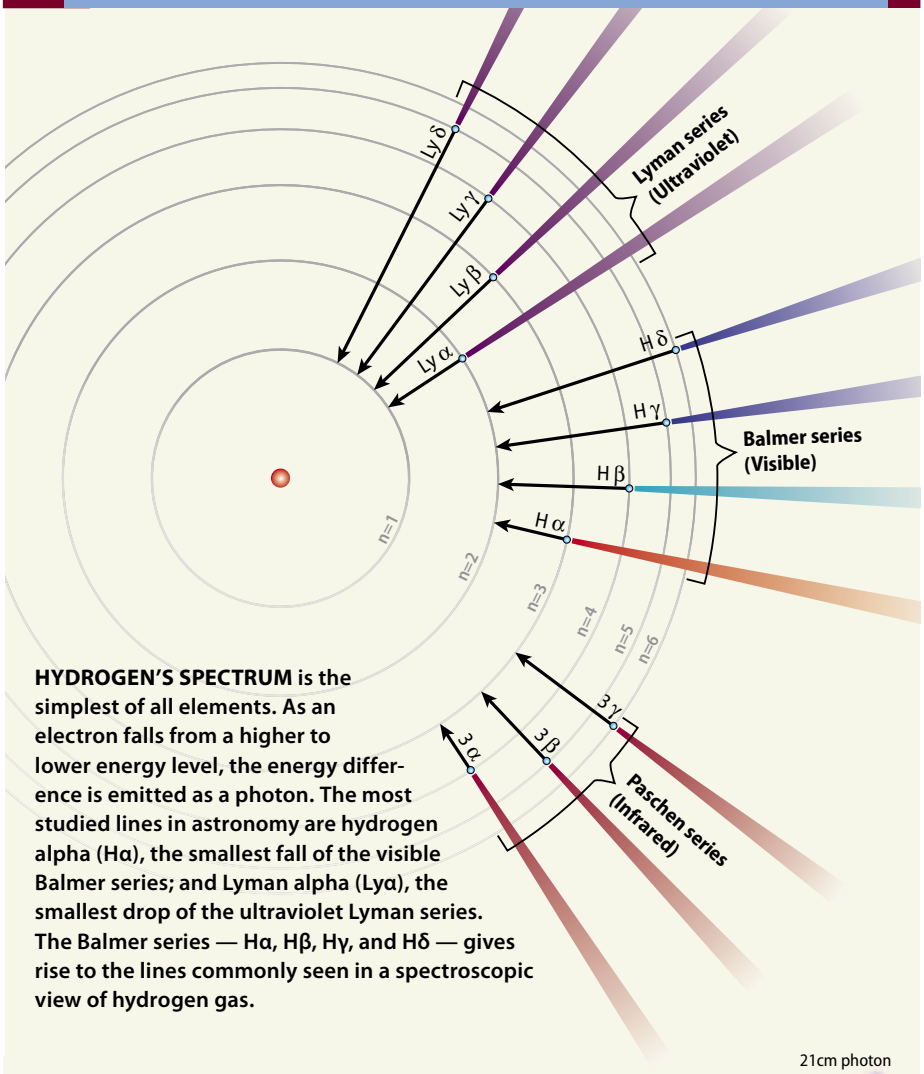
The origin of the first stars has fascinated humanity for centuries, but interest in the reionization epoch is more recent. The research gained momentum in 2003, when investigators on the Wilkinson Microwave Anisotropy Probe (WMAP) team announced that reionization of the universe's intergalactic gas likely occurred roughly 200 million years after the Big Bang, rather than 1 billion years after as previously thought.

WMAP narrowed down the onset of reionization to somewhere between 100 million years (redshift 30) and 400 million years (redshift 11) after the Big Bang, but it could not follow the process over an extended period of time. If reionization occurred early, at redshift 30, it's doubtful any neutral hydrogen instruments currently under development will have the sensitivity to detect it. Background emissions from radio galaxies are noisier at low frequencies because galaxies — including the Milky Way — give off more low-energy, and hence low-frequency, photons than high-energy photons.

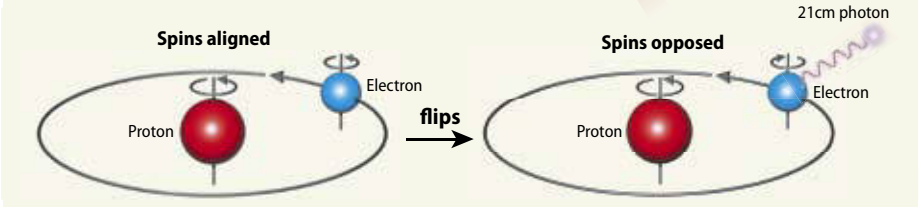
An analysis of two distant quasars' absorption spectra observed by the Sloan Survey suggests more than 10 percent of the universe's hydrogen was still neutral 900 million years after the Big Bang, according to Harvard's Abraham Loeb and University of Melbourne's Stuart Wyithe. The findings were welcome news to MIT radio astronomer Jacqueline Hewitt, who heads MWA's reionization group. "That means it's worth doing this experiment because reionization is still going on," Hewitt says. Even with present capabilities, she adds, "There should be something to see."

*ASTRONOMY:* CHUCK BRAASCH AND ROEN KELLY

/// AT THE ATOMIC LEVEL




**HYDROGEN'S SPECTRUM** is the simplest of all elements. As an electron falls from a higher to lower energy level, the energy difference is emitted as a photon. The most studied lines in astronomy are hydrogen alpha (Hα), the smallest fall of the visible Balmer series; and Lyman alpha (Lyα), the smallest drop of the ultraviolet Lyman series. The Balmer series — Hα, Hβ, Hγ, and Hδ — gives rise to the lines commonly seen in a spectroscopic view of hydrogen gas.




**ZOOMING IN ON THE LOWEST ENERGY LEVEL** — neutral hydrogen's ground state, n=1 in the top diagram — the electron's spin can be either aligned to the proton's spin (left) or opposed (right). As the electron's spin flips from the higher energy state to the lower energy state, it will emit a 21cm wavelength photon.

ASTRONOMY: ROEN KELLY

## Experimental variety

Ironically, much of the technology used in these efforts is not new. "A telescope like PAST could have been built many years ago, but no one made the investment before," says Peterson. He and his fellow astronomers are deploying standard TV and radio antennae — items that can be purchased at a local electronics store.

The ingenuity lies in linking large numbers of these devices in sophisticated ways to make them perform like one large dish. "It takes a lot of computing power to bring the information together, but computing costs keep falling, unlike the cost of steel," notes Morales. "It's an inexpensive way of increasing your sensitivity."

The main projects now underway — LOFAR, PAST, and MWA — all rely on multiple antennae with no moving parts, but their search strategies differ. PAST will point in just one direction — the North Celestial Pole — gaining deep observations of a small field of view.

LOFAR has the longest baseline, a 100-kilometer-diameter array in phase 1, offering the greatest sensitivity. MWA is just 1.5 km across but has the largest field of view. By surveying the sky for longer times, MWA astronomers hope to match LOFAR's sensitivity. Before long, says Morales, "We'll see who guessed right."

Having different instruments with different designs is critical, says Peterson, "because this is difficult astronomy, possibly more difficult than the CMB." While most challenges for CMB astronomy are technical in nature, the main problems for 21cm astronomy lie in the sky.

The radio background glows at a temperature of 200 kelvins — 75 percent of which is from the Milky Way, 25 percent from other radio galaxies and quasars. Whereas the neutral hydrogen signal is a mere 20 millikelvin — 10,000 times dimmer. "We can't identify individual radio galaxies and remove their signal," Peterson says.

Meanwhile, the ionosphere — a layer of ionized particles between 50 and 200 miles above Earth's surface — intermittently reflects radio waves, creating havoc for radio astronomers. At higher redshifts (and lower frequencies), the problem gets worse.

Radio frequency interference from TV and radio transmitters and airplanes further confounds matters. "It's definitely going to be hard," admits Chris Carilli of the National Radio Astronomy Observatory. "If it were easy, we'd have done it already."

## Resolving a history

Astronomers are spurred on by the potential payoff. "21cm measurements offer the richest data set on the universe's initial conditions that we can see on the sky," says Loeb. Calculations he did with Harvard colleague Matias Zaldarriaga show neutral hydrogen anisotropies "contain an amount of information orders of magnitude larger than any other cosmological probe," says Loeb.

Whereas CMB measurements are taken at just a single redshift — one moment in cosmic time — neutral hydrogen measurements

**Steve Nadis,** *a frequent* Astronomy *contributing editor, lives in Cambridge, Massachusetts. His less serious prose can be found at his web site: cambridgeguy.blog.com.*

can sample an entire volume by looking at numerous redshifts, and hence different times. The result should be the definitive history of hydrogen in the universe.

To search the Dark Ages, astronomers have designed instruments that can explore both available spectra: absorption and emission. In early epochs, when the universe's gas was colder than the microwave background, neutral hydrogen absorbed CMB flux, leaving an imprint on the low-frequency (radio) end of the spectrum.

Astronomers can trace the distribution of neutral hydrogen in this era by finding regions with fewer CMB photons. The technique, according to Loeb and Zaldarriaga, could detect hydrogen clumps in the nascent universe 300 light-years across — a resolution roughly 1,000 times better than WMAP's.

Once neutral hydrogen is heated above the CMB temperature by the first stars (but before reionization), the gas will emit 21cm radiation. Says Carilli, "The 21cm line is the only direct probe we have of the neutral intergalactic medium."

The absorption signal has a lower frequency, and therefore, longer wavelengths than the emission signal because absorption and emission occurred in different epochs.

## Bubbly universe

The distribution of this neutral gas, in turn, can reveal whether the ionizing sources are predominantly stars or quasars. Each primordial light source carves out a bubble of ionized gas within an otherwise neutral sea. Over time, the bubbles expand and overlap until reionization is complete.

There are two scenarios — ionization by stars and galaxies, or by quasars — leading to geometrically distinct pictures. "If quasars dominated the process, there should be a small number of large bubbles," explains Loeb. "If normal galaxies drove reionization, there'd be a large number of small bubbles."

From an observational standpoint, bubbles around distant quasars are the easiest places to start probing reionization because they're dramatic features whose positions are well known. Lincoln Greenhill of the Harvard-Smithsonian Center for Astrophysics intends to use the Very Large Array (VLA) in New Mexico to study these bubbles.

In collaboration with Carilli and others, Greenhill wants to install a dipole antenna and receiver on each of VLA's 28 dishes to intercept low-frequency radio signals. The initial plan is to examine the three most distant known quasars, all lying beyond redshift 6.2 in the reionization epoch.

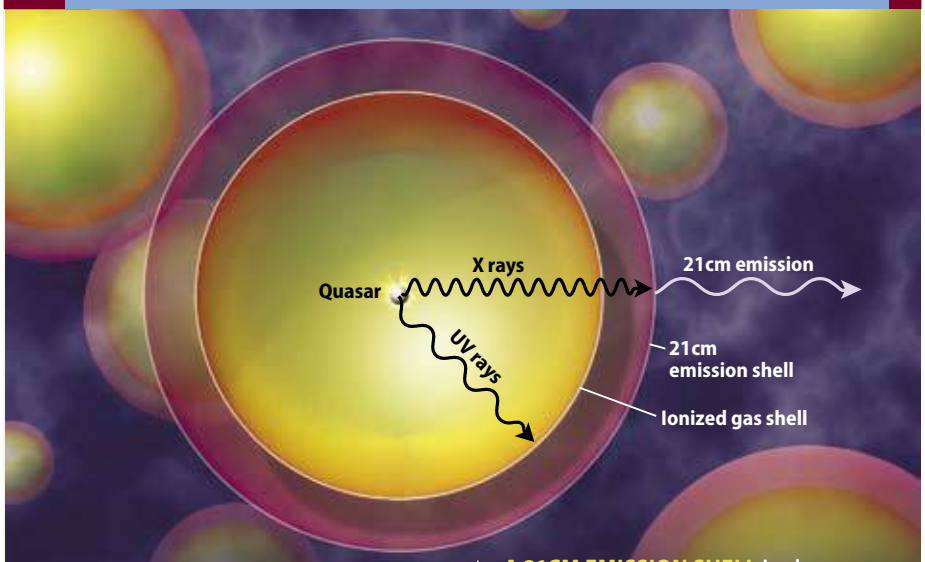
When other far-flung quasars are discovered, they'll be added to the list. By taking advantage of VLA's existing infrastructure, says Greenhill, "We can do this fast and cheap." With the Smithsonian Astrophysical Observatory covering the $100,000 equipment costs, they just need to secure telescope time, possibly starting late this year.

Greenhill and his colleagues will focus on the thin "emission shell" lying at the edge of the bubble — the most likely source of 21cm radiation. X rays from the quasar penetrate and heat the neutral gas, giving rise to 21cm emissions.

The quasar's ultraviolet photons, which are absorbed strongly by the neutral medium, arrive later, ionizing the gas and thereby ceasing emissions [see "Hydrogen bubbles," below]. Greenhill hopes to determine the size and expansion rate of the bubbles, while gathering details about the surrounding medium.

After first tackling the most extreme cases — quasar bubbles — radio astronomers will attempt to observe ever-smaller fluctuations until the neutral hydrogen background is fully mapped. The ultimate goal, says Carilli, is "3-D tomography" — the equivalent of a CT scan of the universe.

### /// HYDROGEN BUBBLES




**A 21CM EMISSION SHELL** is always radiating away just ahead of the shell of ionized gas. By looking for these shells, or bubbles, astronomers will be able to map reionization.

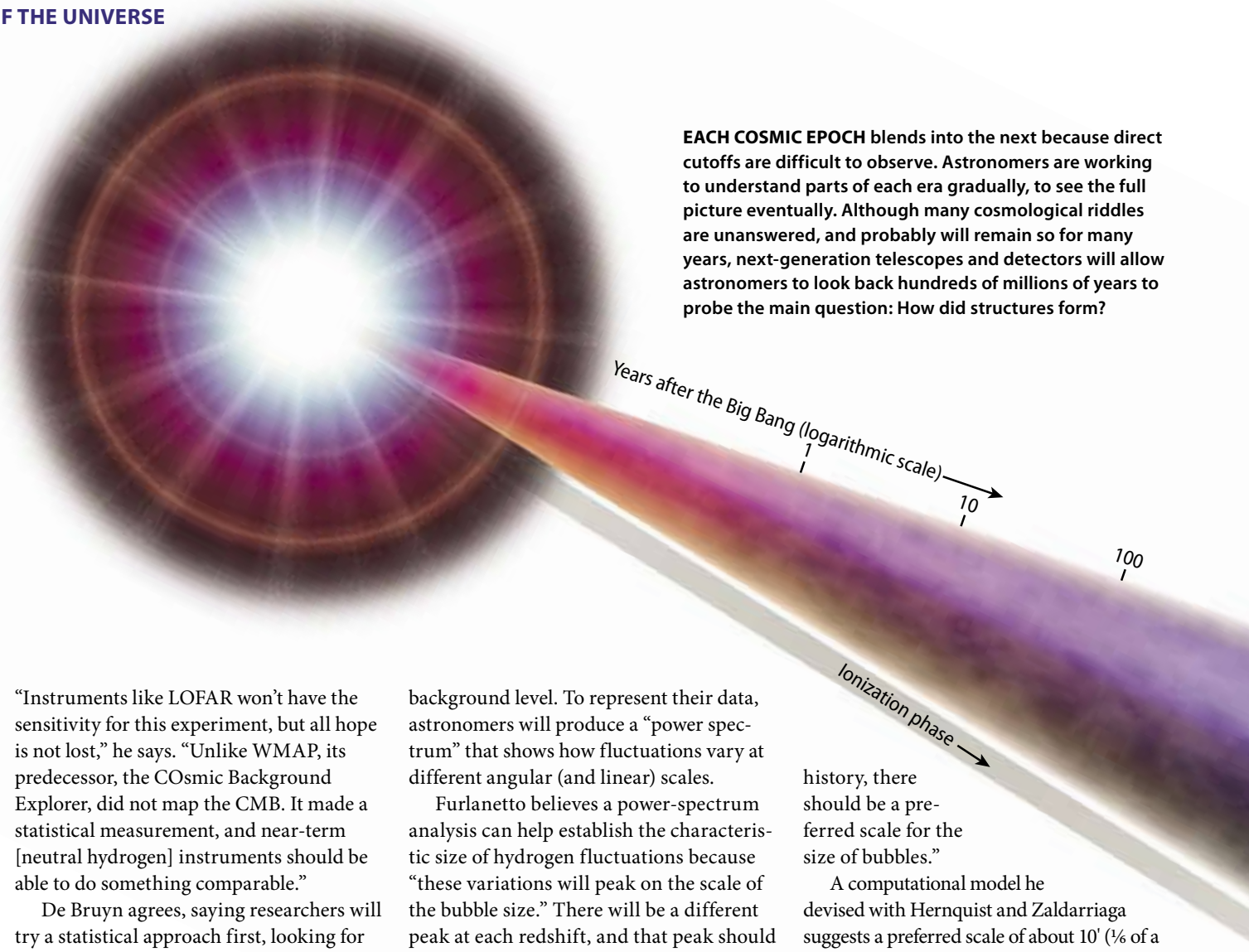
Quasars emit both ultraviolet (UV) and X-ray photons. Although both types of photons travel at the speed of light, higher-energy X rays interact less with the surrounding media, and thus get out faster.

UV photons ionize most of the neutral hydrogen gas because they are more abundant and the gas absorbs these lower-energy photons more easily. Energy from the UV photons ionizes the hydrogen by stripping away electrons from the hydrogen nuclei. As ionization continues — primarily by UV photons — a cavity of ionized gas forms and grows around the quasar, just like a steadily inflating bubble.

The X rays propagate through the gas with less energy loss — and penetrate farther — because they are less likely to be absorbed. They heat the gas, therefore, without ionizing it, giving rise to 21cm radiation. As X rays propagate outward from the quasar, a thin emission shell — where 21cm emission takes place — forms just beyond the ionized bubble.

When the UV photons reach this shell, the gas is ionized, and emission ends. However, at that point, the X rays have penetrated even farther into the neutral medium to heat the outlying neutral hydrogen gas, giving rise to additional 21cm radiation. The emission shell moves outward radially, always one step ahead of the UV-driven ionization front. — *S. N.*

ASTRONOMY: ROEN KELLY




**EACH COSMIC EPOCH blends into the next because direct cutoffs are difficult to observe. Astronomers are working to understand parts of each era gradually, to see the full picture eventually. Although many cosmological riddles are unanswered, and probably will remain so for many years, next-generation telescopes and detectors will allow astronomers to look back hundreds of millions of years to probe the main question: How did structures form?**

"Instruments like LOFAR won't have the sensitivity for this experiment, but all hope is not lost," he says. "Unlike WMAP, its predecessor, the COsmic Background Explorer, did not map the CMB. It made a statistical measurement, and near-term [neutral hydrogen] instruments should be able to do something comparable."

De Bruyn agrees, saying researchers will try a statistical approach first, looking for fluctuations — both excesses and deficits in 21cm emissions compared to the average background level. To represent their data, astronomers will produce a "power spectrum" that shows how fluctuations vary at different angular (and linear) scales.

Furlanetto believes a power-spectrum analysis can help establish the characteristic size of hydrogen fluctuations because "these variations will peak on the scale of the bubble size." There will be a different peak at each redshift, and that peak should grow over time. Therefore, Furlanetto says, "At each epoch in the reionization history, there should be a preferred scale for the size of bubbles."

A computational model he devised with Hernquist and Zaldarriaga suggests a preferred scale of about 10' (⅙ of a degree — equivalent to several millions of light-years in length) for bubbles in the middle of reionization. Today's instruments are aiming for that same scale.

## Good "seeing"

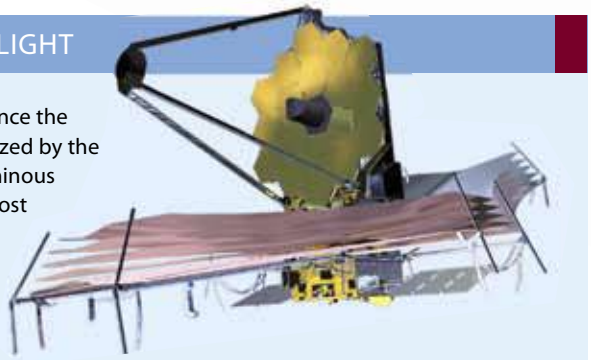
Initially, LOFAR will look for the characteristic sizes of ionized hydrogen bubbles, beginning its search around 2007. The array will consist of 15,000 antennae deployed in a five-arm spiral, spread out over a 100-kilometer-diameter area in phase one. Morales is skeptical about LOFAR's chance for success in such a densely-populated area. With competing radio and TV signals, he says "It's like doing astronomy in an outdoor disco."

De Bruyn is confident his team can deal with those challenges, but he acknowledges the site's shortcomings. For starters, they'll have to curtail observations at redshift 11.5 to avoid interference from FM radio broadcasts. But optical

### /// WHEN THERE WAS LIGHT

The cosmic Dark Ages ended once the universe was completely reionized by the first stars and galaxies. The luminous period that followed holds almost as many questions as the Dark Ages. Because astronomers know important steps in structure formation occurred shortly after the Dark Ages ended and the stars ignited, they expect to explore this era soon.

With the formation of the first galaxies, starlight was absorbed by dust and re-emitted in the infrared. Astronomers think the light from this process created a "cosmic infrared background." By studying this re-emitted light, astronomers can observe the "structural clumpiness" of the early universe.



NORTHROP GRUMMAN SPACE TECHNOLOGY

**SCHEDULED FOR A 2011 LAUNCH, the James Webb Space Telescope — Hubble's infrared successor — will look back to early galaxy formation.**

The infrared radiation traces the distribution of early protogalaxies, and this information will add to the understanding of the universe's structural evolution. — *Liz Kruesi*

astronomers also have to adapt to clouds and inclement weather, he says. "Not everyone can observe in Hawaii or Chile. Just because one site is best doesn't mean other sites can't support good science."

In contrast to LOFAR's crowded setting in the Netherlands, PAST sits in the remote Ulastai Valley of western China, shielded from interference by high mountains. "We can choose our frequencies on the basis of cosmology," says Peterson, rather than the whims of FM broadcasting. With 8,000 antennae expected to be in place by late 2005, PAST will survey the regions that existed 200 million years after the Big Bang, before they grew into the large-scale structures we see today.

In Australia, MWA has a similar target, aiming for great big lumps of neutral hydrogen that will eventually become galaxy clusters, rather than individual galaxies. Although PAST will have a larger collecting area — 80,000 square meters versus MWA's 8,000 — MWA can point in any direction. "We'll look for holes in the galactic radio emissions," says Morales, "seeking out the quietest, darkest places in the sky." Current plans call for an early 2007 start date, assuming the U.S. team can contribute its share of the cost.

## Groundwork for the future

If any team makes a significant detection, the neutral hydrogen signal will have to be confirmed by more than one instrument because of its faintness on the radio sky. Verification has proved crucial in CMB findings, notes Peterson, and it underscores the value of having multiple instruments and multiple approaches.

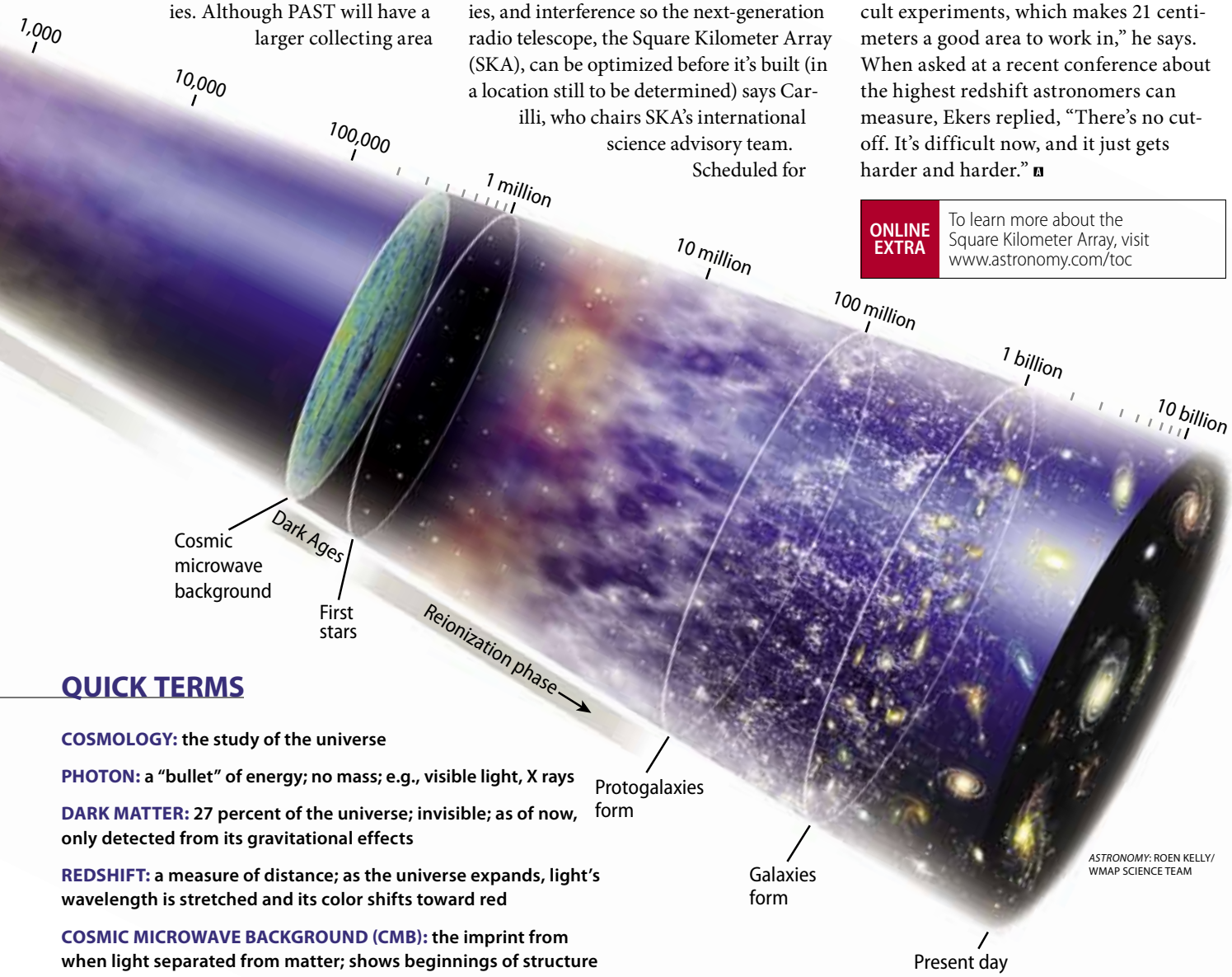
These early "pathfinder experiments" can help astronomers confront the challenges posed by the ionosphere, radio galaxies, and interference so the next-generation radio telescope, the Square Kilometer Array (SKA), can be optimized before it's built (in a location still to be determined) says Carilli, who chairs SKA's international science advisory team. Scheduled for operation in 2020, SKA will have roughly 10 times the collecting area of LOFAR.

With the added sensitivity, says Carilli, "We can go from imaging the most extreme objects in the universe to imaging normal objects." The goal is to examine small angular scales to chart the early clumpiness of neutral hydrogen, which should tell astronomers about structure formation, inflation, dark matter, and other cosmic riddles.

If things go well, there's the potential to extract a wealth of information from the neutral hydrogen signal, says Zaldarriaga. But he still considers the proposition dicey. "Whether or not this can be done in practice remains to be seen."

Ron Ekers, a radio astronomer based at CSIRO — Australia's national scientific research organization — who is trying to pinpoint the timing of reionization, is up for the challenge. "I'm attracted to difficult experiments, which makes 21 centimeters a good area to work in," he says. When asked at a recent conference about the highest redshift astronomers can measure, Ekers replied, "There's no cutoff. It's difficult now, and it just gets harder and harder."

**ONLINE EXTRA** To learn more about the Square Kilometer Array, visit www.astronomy.com/toc




*ASTRONOMY*: ROEN KELLY/ WMAP SCIENCE TEAM

## QUICK TERMS

**COSMOLOGY:** the study of the universe

**PHOTON:** a "bullet" of energy; no mass; e.g., visible light, X rays

**DARK MATTER:** 27 percent of the universe; invisible; as of now, only detected from its gravitational effects

**REDSHIFT:** a measure of distance; as the universe expands, light's wavelength is stretched and its color shifts toward red

**COSMIC MICROWAVE BACKGROUND (CMB):** the imprint from when light separated from matter; shows beginnings of structure

BY MARTIN RATCLIFFE AND ALISTER LING

# AUGUST 05

Warm August nights provide the perfect opportunity to see a dark sky full of stars and the glory of our galaxy.

## Year of the Perseids

One of the year's best shows of "shooting stars" makes its annual return in mid-August. On the night of the peak (August 11/12), you can expect to see an average of one meteor every minute after midnight from a dark location. Earlier in the evening, rates likely will run half that. From a typical suburban backyard, you might see only one meteor every 10 minutes. See "Meteors and moons" on page 60 and "Star shower" on page 70 for more details.

An enjoyable activity on a sunny summer day is to view the Sun. If you don't have a safe solar filter, head to the nearest planetarium or science center. Chances are it will have set up solar telescopes, and you can talk to a knowledgeable person about proper filters.

The first thing you'll notice on the Sun's disk are several black dots — sunspots. During the course of an afternoon, you often can see a large sunspot change structure slightly. If you can look through an H-alpha filter, you'll likely see one or two prominences, large tongues of red flame that arch above the solar limb.

Brilliant Venus begins to shine through the evening twilight 30 to 45 minutes after sunset. Thanks to a bad viewing angle from north of the equator, the beacon remains low in the west throughout this evening apparition.

Jupiter puts on its last telescopic hurrah during August.

STEVE TRAUDT

**A PERSEID FIREBALL streaks parallel to the Milky Way's spine. August nights offer great opportunities to view both meteors and Milky Way highlights.**

The bright, pale-yellow "star" low in the west-southwest after sunset is the biggest planet in the solar system. The earlier in the evening you observe it, the better chance you have of a good look. When an object lies low in the sky, its light travels a longer path through Earth's lower atmosphere, increasing the chances of encountering image-spoiling turbulence.

Because Earth orbits the Sun faster than Jupiter does, the giant planet appears to sink toward the Sun. This sets up a conjunction with Venus at the end of August. The two planets lie low in the sky during twilight, however, so they won't be as impressive as in November 2004's morning sky.

Will Comet 9P/Tempel 1 sport a spike this month? Astronomers hope the July 4 slap across the face from the Deep Impact spacecraft will create a new jet for all to see. The dirty snowball hangs low above the southern horizon as the sky darkens. Another comet, 161P/Hartley-IRAS, remains in view near the Big Dipper all night.

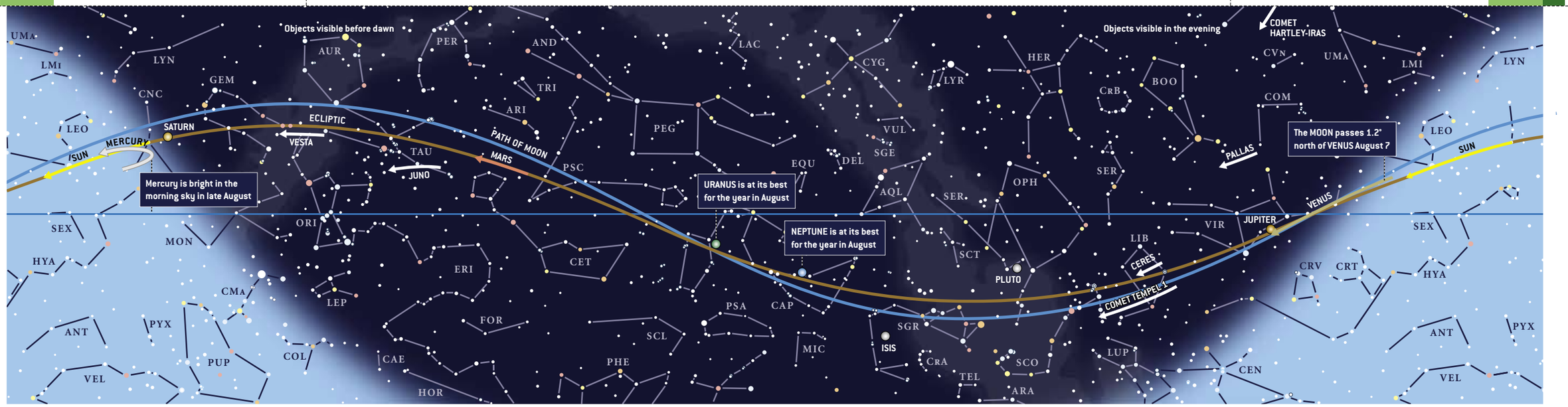
Although the Moon lies in hiding at the start of the month, it climbs into the evening twilight to pair with Venus August 7. Because of the objects' low elevation, this will be a binocular event for most of us. In Alaska and the Yukon, the Moon blots out Venus just before sunset. You'll need a carefully orchestrated plan to bag this rare event.

If you think the Moon looks lower than normal, you're not crazy. From First Quarter to Full Moon, our satellite lies almost as far south as it can get. It hits the "bottom" of its 18.6-year cycle next summer. From south of the equator, the Moon reaches its high point.

With summer nights so short, it's easier to stay up until dawn. Mars appears high in the south by this time, its bright orange glow seemingly out of place in this quiet area of sky. Although small, Mars' disk has grown big enough to reward patient observers with subtle details. Magnificent Saturn will keep you going until Mercury breaches the horizon. The crescent Moon joins the parade the mornings of August 31 to September 2.

# Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.




[ 07 ] [ 06 ] [ 05 ] [ 04 ] [ 03 ] [ 02 ] [ 01 ]

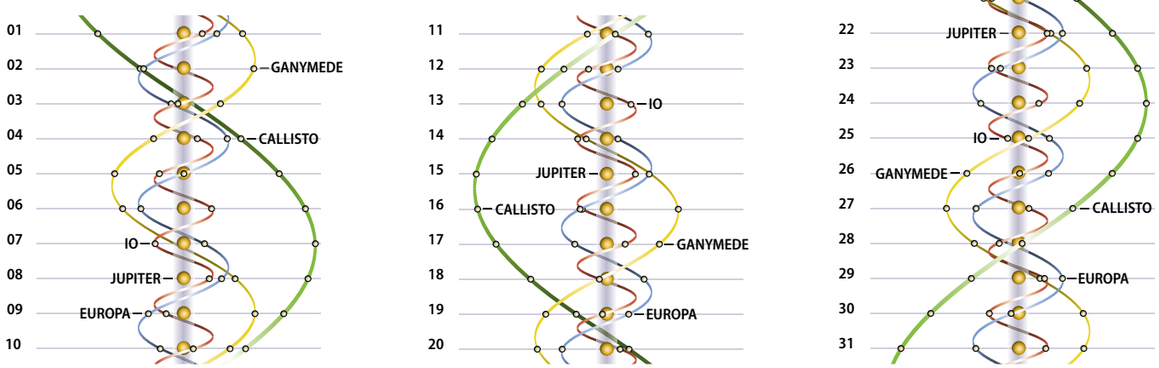
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

[ 31 ] [ 30 ] [ 29 ] [ 28 ] [ 27 ] [ 26 ] [ 25 ] [ 24 ] [ 23 ] [ 22 ] [ 21 ] [ 20 ] [ 19 ] [ 18 ] [ 17 ] [ 16 ] [ 15 ] [ 14 ] [ 13 ] [ 12 ] [ 11 ] [ 10 ] [ 09 ] [ 08 ] [ 07 ] [ 06 ] [ 05 ] [ 04 ]

| PLANETS | MERCURY | MERCURY | VENUS | MARS | MARS | JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | August 15 | August 31 | August 15 | August 1 | August 31 | August 15 | August 31 | August 15 | August 15 | August 15 |
| Magnitude | — | −1.0 | −3.8 | −0.5 | −1.0 | −1.8 | 0.3 | 5.7 | 7.8 | 13.9 |
| Angular size | 9.6" | 6.1" | 13.3" | 11.3" | 14.0" | 32.9" | 16.7" | 3.7" | 2.4" | 0.1" |
| Illumination | 12% | 71% | 80% | 84% | 87% | 99% | 100% | 100% | 100% | 100% |
| Distance (AU) from Earth | 0.704 | 1.102 | 1.256 | 0.829 | 0.668 | 5.999 | 9.928 | 19.099 | 29.054 | 30.482 |
| Distance (AU) from Sun | 0.369 | 0.308 | 0.724 | 1.383 | 1.395 | 5.453 | 9.088 | 20.069 | 30.061 | 30.991 |
| Right ascension (2000.0) | 8h41.3m | 9h37.4m | 11h51.8m | 2h03.6m | 3h00.0m | 12h58.5m | 8h32.4m | 22h45.0m | 21h13.8m | 17h26.5m |
| Declination (2000.0) | 15°00' | 15°10' | 1°48' | 9°36' | 14°10' | −5°00' | 19°12' | −8°48' | −16°11' | −15°09' |

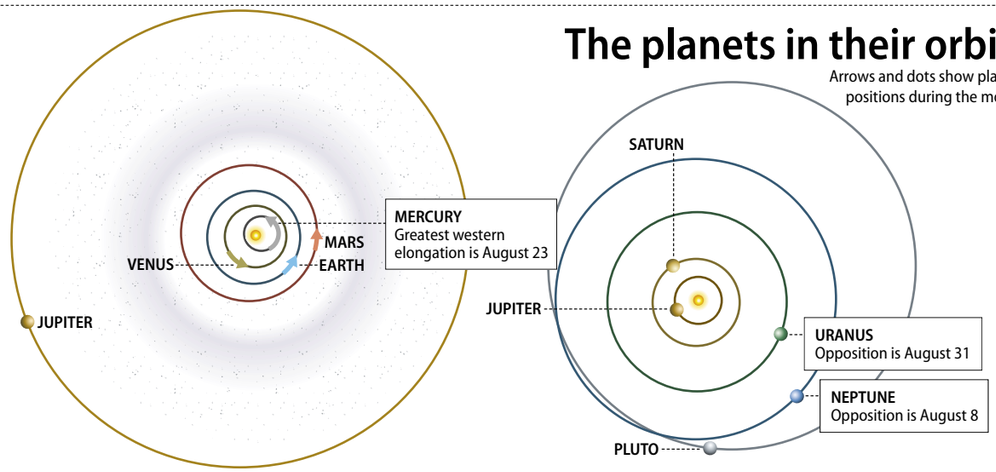
## Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.



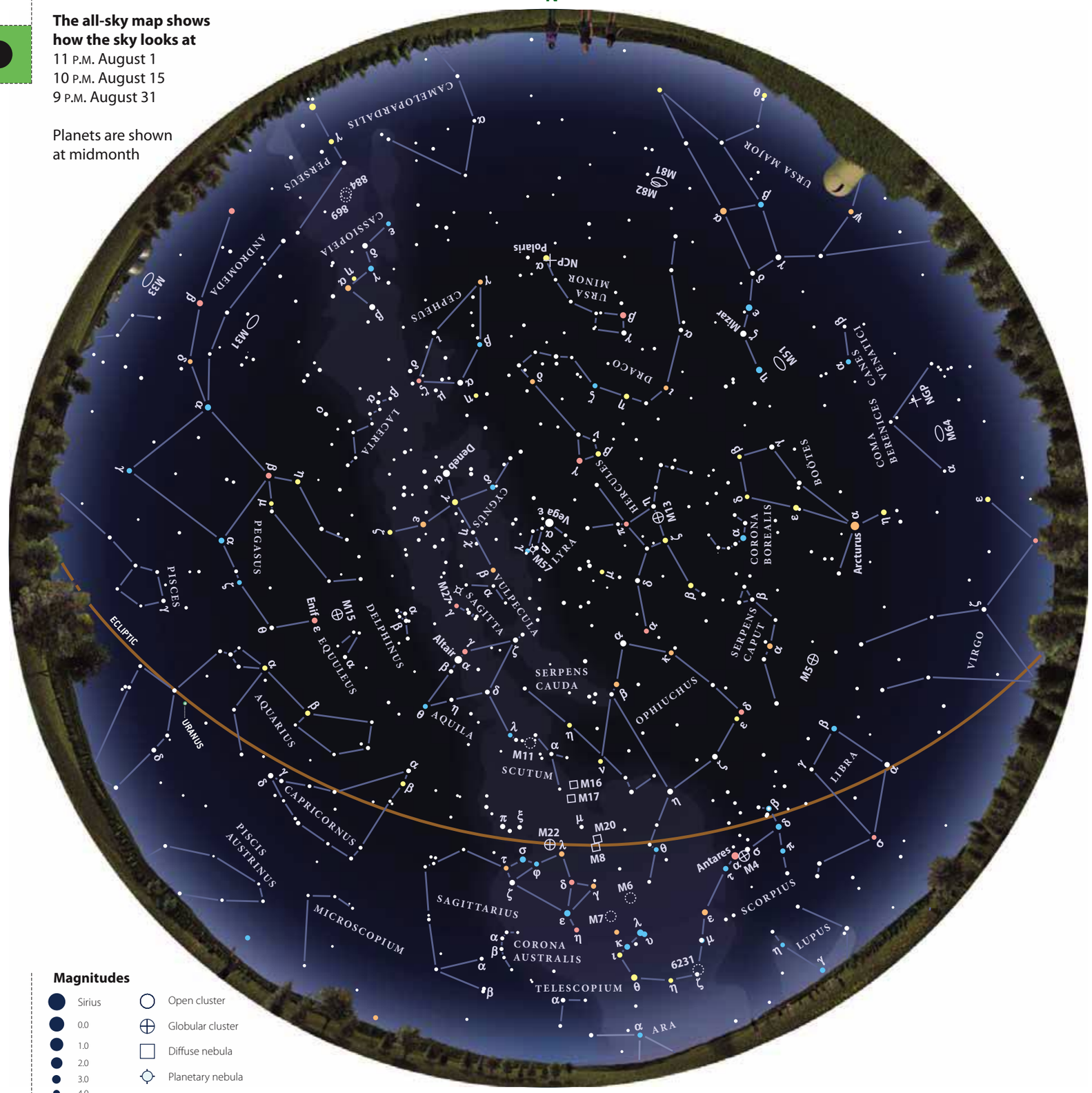

## The planets in their orbits

Arrows and dots show planets' positions during the month.



**The all-sky map shows how the sky looks at**
11 P.M. August 1
10 P.M. August 15
9 P.M. August 31

Planets are shown at midmonth




**Magnitudes**

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

# august 05

| SUN. | MON. | TUES. | WED. | THURS. | FRI. | SAT. |
|---|---|---|---|---|---|---|
| | [01] | [02] | [03] | [04] | [05] | [06] |
| [07] | [08] | [09] | [10] | [11] | [12] | [13] |
| [14] | [15] | [16] | [17] | [18] | [19] | [20] |
| [21] | [22] | [23] | [24] | [25] | [26] | [27] |
| [28] | [29] | [30] | [31] | | | |

**04** The Moon is at apogee (252,669 miles from Earth), 5:48 P.M. EDT

New Moon is at 11:05 P.M. EDT

**07** The Moon passes 1.2° north of Venus, midnight EDT

**08** Neptune is at opposition, noon EDT

**10** The Moon passes 1.3° south of Jupiter, 4 A.M. EDT

**12** Perseid meteor shower peaks

First Quarter Moon is at 10:38 P.M. EDT

**14** The Moon passes 0.4° north of Antares, 9 A.M. EDT

**18** The Moon passes 5° south of Neptune, 7 P.M. EDT

**19** The Moon is at perigee (222,074 miles from Earth), 1:36 A.M. EDT

Full Moon is at 1:53 P.M. EDT

**20** The Moon passes 2° south of Uranus, 8 A.M. EDT

**23** Mercury is at greatest western elongation (18°), 7 P.M. EDT

**25** The Moon passes 6° north of Mars, 3 A.M. EDT

**26** Last Quarter Moon is at 11:18 A.M. EDT

**31** The Moon passes 5° north of Saturn, 1 P.M. EDT

The Moon is at apogee (252,409 miles from Earth), 10:35 P.M. EDT

Uranus is at opposition, 11 P.M. EDT

**ONLINE EXTRA** For definitions of terms, visit www.astronomy.com/glossary

# THE DEEP SKY

Summer camping trips and star parties offer great chances to view the wonders of the Milky Way.

CARL WEBER

**THE LAGOON NEBULA (M8)** harbors hundreds of massive stars that pour out energetic radiation, causing the surrounding gas to glow.

## Clusters near the core

The awakening of the astronomer within us often happens when we first see the night sky at its best. Suddenly, the Milky Way no longer appears as just a misty glow, but as a glorious, edge-on spiral galaxy brimming with gas clouds, dust, and star clusters. The evening view of our galaxy sweeps from a distant spiral arm in the northeast, brightens overhead as the next arm looms closer, and broadens to a magnificent center commanding the southern horizon.

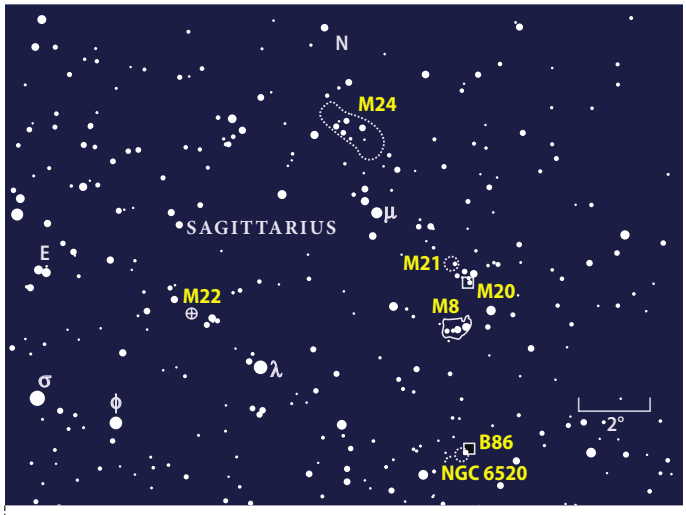
The galaxy's center surprisingly is not where the milky glow looks brightest. Try as we might, our eyes cannot penetrate to the core. Thousands of light-years of dust laced throughout the spiral arms hide the center completely.

Aim your binoculars at the brightest section in the south. Here, you will see a misty glow — the Lagoon Nebula (M8) — summer's answer to winter's great Orion Nebula. Hot, young stars flood this neighborhood with high-energy radiation, making gas clouds glow. Just above the Lagoon lies another star nursery, the Trifid Nebula (M20). You'll need an 8-inch scope to see clearly the dark lanes that give this nebula its name. A group of teenage stars, M21 has shed its natal cocoon, making it easy to spot its brightest members through binoculars. Keep sliding north and you'll soon run across an amazing concentration of stellar pinpoints — the Small Sagittarius Starcloud (M24).

Spend some time observing M24 through a telescope. Start at low power to get an overall picture, and sweep around slowly, watching how the star density changes. It's as if a celestial artist had flicked a brush full of black paint onto the canvas, obliterating stars in random blobs. Once again, this is light-years of dust blocking our view. One day in the distant future, this dust will be processed into stars and planets. Bump up the power to get a good look at the nearly innumerable stars filling the eyepiece.

If this isn't enough, point your scope to the upper left of Sagittarius' teapot lid. There you'll find M22, a nearby globular star cluster. At low power in a small scope, M22's bright, somewhat oval shape does not betray its true identity. An 8-inch scope cranked up to 200x or more transforms this diffuse cotton ball into a stunning swarm of stars, this time surely beyond your ability to count. If you're at a star party and a big-scope owner kindly takes requests, ask for this showpiece.

The mismatched pair NGC 6520 and B86 ranks among many observers' all-time favorites. From the city, it's a ho-hum sight — don't disappoint yourself. Under dark skies, the lovely star cluster NGC 6520 sits on a concentrated bed of fine stardust, making a stark contrast to the jet-black dust cloud Barnard 86 immediately adjacent. For maximum punch, center a big scope operating at about 250x on the black space. Then, let Earth's rotation carry in the astonishing mass of stars crowding the galaxy's inner spiral arms.



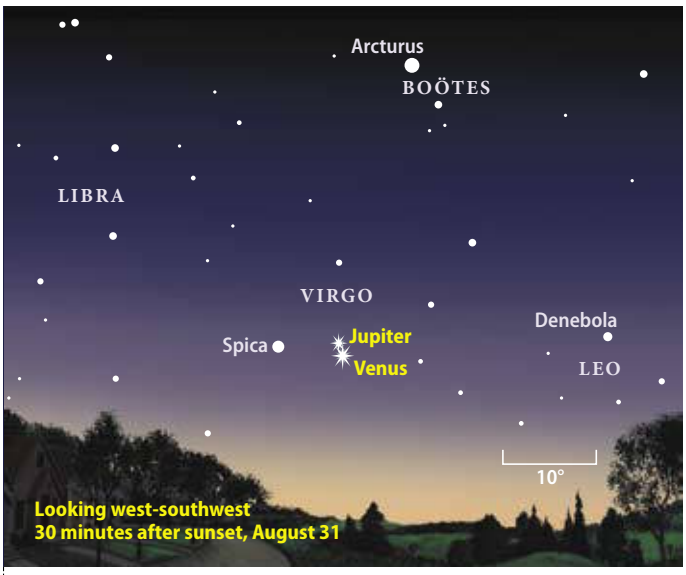

ASTRONOMY: ROEN KELLY

**THE MILKY WAY'S CENTRAL REGION** contains the highest concentration of bright deep-sky wonders in the entire sky.

**Martin Ratcliffe** *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

# THE PLANETS

Venus and Jupiter make a dramatic pair in the evening sky late this month, while the outer gas-giant planets reach the peak of their yearly apparitions.




ASTRONOMY: ROEN KELLY

**VENUS AND JUPITER come together low in the western twilight during the final week of August.**

The two brightest planets — **Venus** and **Jupiter** — begin August 30° apart in the western sky after sunset, and will appear to get closer during the month. At magnitude –3.8, Venus shines 2 magnitudes brighter than Jupiter. Venus' elongation from the Sun increases this month, but the planet continues to hug the horizon as it moves south in declination. During the next few months, Venus will set farther south of due west just like the Sun.

Through a telescope, Venus displays a disk slightly more than three-quarters lit. This cloud-covered world, which spans 13" this month, reveals few other details. Between August 7 and 9, a thin crescent Moon joins the two planets.

Jupiter lies about 5 times farther from Earth than Venus. But with nearly 12 times the physical diameter of Venus, Jupiter shows a significantly larger disk through a telescope. This month, Jupiter measures 33" across.

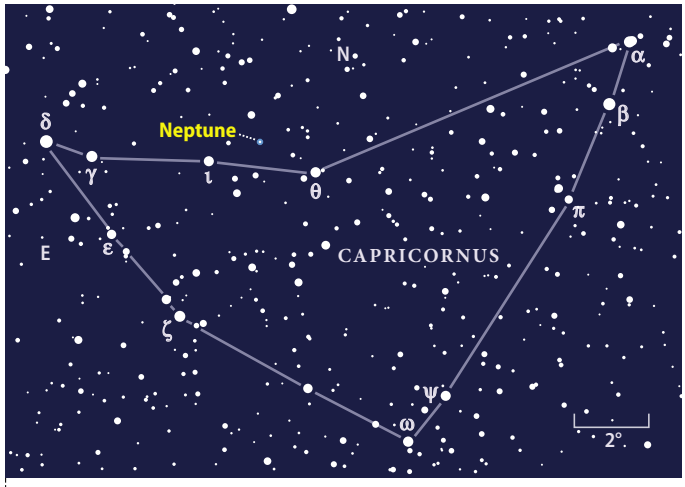
Each evening during August, Jupiter and Venus appear 1° closer to each other. Do the math, and you'll find the two are destined to be next to each other by month's end. On August 31, the two bright planets lie just 4 Moon-widths apart, making a stunning evening pair. They'll appear slightly closer the first evening of September.

Jupiter sets earlier each night, so quality observing time dwindles throughout the month. On August 1, it sets around 11 P.M. local daylight time. By the end of the month, it disappears from view near the end of twilight.

A small telescope easily reveals the wanderings of Jupiter's four Galilean moons. If you're a newcomer to watching Jupiter, it's worth spending time identifying each moon. Make a sketch of their positions relative to Jupiter each clear night. You'll soon notice some patterns emerging in each moon's motion. Io, the innermost large moon, scoots around Jupiter in less than 2 days. Callisto, the outermost major moon, takes more than 2 weeks to complete a single orbit of Jupiter.

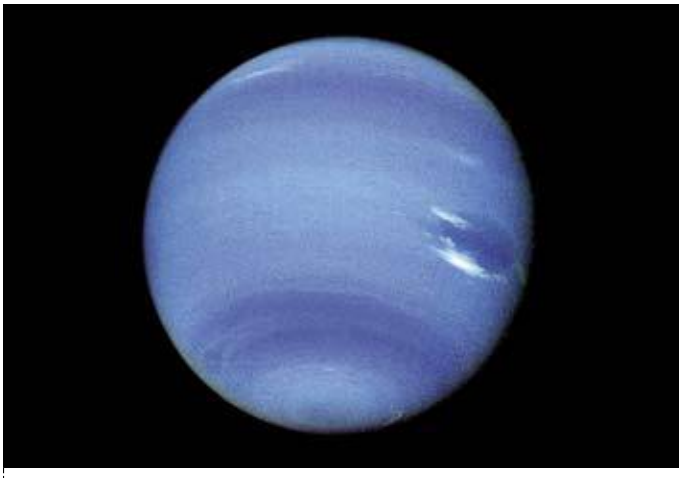
Going from one extreme to the other, **Pluto** is the smallest, faintest planet in the solar system. It lies in the southwestern corner of Serpens Cauda, 2.5° west of the 3.5-magnitude star Xi (ξ) Serpentis. You'll need an 8-inch or larger telescope and a transparent, moonless sky to find the outermost planet, which glows at magnitude 13.9.

**Neptune** reaches opposition and best visibility August 8. You can find it with binoculars or a telescope in Capricornus the Sea Goat about 1° due south of 5th-magnitude 29 Capricorni. During August, Neptune wanders slowly to the southwest in the general direction of 4th-magnitude Theta (θ) Capricorni. The planet lies 2.7 billion miles from Earth at opposition, so even though it then glows brightest, it is still faint at magnitude 7.8. Its blue-gray disk appears 2.4" across, just big enough to be resolved under good conditions. Capricornus lies low in the southeast during the early evening hours, but stands high up in the south by midnight.




ASTRONOMY: ROEN KELLY

**NEPTUNE REACHES OPPOSITION August 8, when it glows at 8th magnitude about 1° south of 5th-magnitude 29 Capricorni.**



NASA/JPL

**DISTANT NEPTUNE reaches best visibility in August, although it will show a bland, blue-gray disk and not the rich features seen by the Voyager 2 spacecraft in 1989.**

Neptune's closer cousin, **Uranus**, reaches opposition the American evening of August 31. (In Europe, Africa, Asia, and Australia, the calendar reads September 1.) This is the best time of year to view this distant gas giant. Look for it near local midnight in the southern sky. Uranus lies in the same binocular field of view as Lambda (λ) Aquarii, and is itself an easy binocular target. It glows at magnitude 5.7 and looks just like a star of that brightness. A telescope easily reveals its 3.7"-diameter disk, which has a distinct blue-green color.

**Mars** enters the late evening sky during August, and rises well before midnight by the 31st. It still appears best before dawn, however, when it lies high in the south. The planet's south polar cap continues to erode as summer begins in that hemisphere (the summer solstice occurs August 16).

This seasonal moment places the south polar cap on fine view for earthbound observers, while the northern cap tilts away from us. Mars exhibits a strong gibbous phase during August, although it does diminish slowly. Last month's minimum of 84-percent illumination grows to 87 percent by August's end. Any telescope will show the planet's orange disk as distinctly non-round.

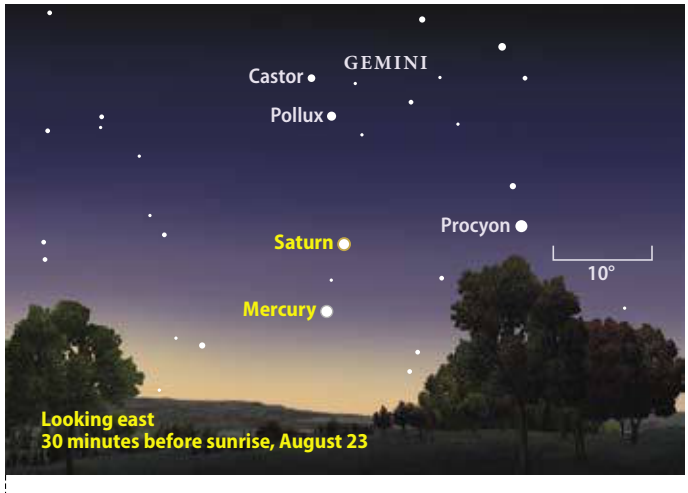
Mars brightens rapidly during August as its distance from Earth decreases. It reaches magnitude –1.0 August 31, about 60-percent brighter than early in the month. This coincides with its distance from Earth dropping from 77 million miles to 62 million miles. As you might guess, Mars also appears larger when viewed through a telescope. Its disk grows more than 20 percent during August, from 11.3" to 14.0". By the time Mars reaches opposition in early November, its disk will appear nearly 50-percent larger.

As the south polar cap slowly disappears, watch carefully for cloud features that likely will appear around the polar cap and along the terminator. Colored filters designed for planetary viewing will aid their visibility. Other familiar martian features also exhibit changes, including Syrtis Major, Solis Lacus (the "eye of Mars"), and the Hellas basin. Now is the time to start observing carefully. Photograph or sketch what you see so you become familiar with these features by the time the best views arrive around its November 7 opposition.

A webcam video of Mars through a well-adjusted telescope (collimated, sharp focus, excellent tracking) provides data perfect for use with video frame-stacking programs. Practice your technique now, and by the time opposition comes, you'll be getting results that were reserved for a handful of imaging experts just a few years ago. Today's technology is revolutionizing the methods available for recording planetary features. Further details about observing Mars are at the web site of the Association of Lunar and Planetary Observers, *www.lpl.arizona.edu/alpo*.

As if to complement the great Venus-Jupiter conjunction in the evening sky, **Saturn** and **Mercury** meet each other in a more subtle pairing before dawn. After August 20, both planets should be easy to spot low in the east-northeast an hour before sunrise. Saturn then shines at magnitude 0.3, and Mercury, located 6° below Saturn, shines at magnitude 0.4. During the remaining days of August, Saturn continues to rise earlier, while Mercury draws away from Saturn. Mercury continues to brighten through the end of the month. On August 31, it shines at magnitude –1.0. Saturn stands 16° higher, with a slender crescent Moon just 5° to its north. Next month, Mercury will pass close to Leo's brightest star, Regulus.

The August 19 Full Moon occurs just 12 hours after perigee, the Moon's closest point to Earth. Our satellite will then appear 10-percent larger than average, spanning 33.25'.




*ASTRONOMY*: ROEN KELLY

**SATURN EMERGES from morning twilight in late August, when it joins up with innermost Mercury.**

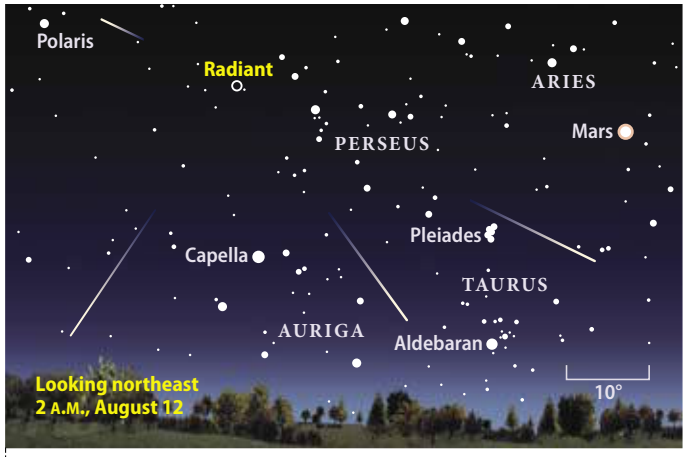
# METEORS AND MOONS

Everyone's favorite meteor shower peaks August 11/12, when the Moon is gone from the morning sky. A few days later, several prominent lunar craters near Mare Frigoris come into view.

## A summer shower

Although the Perseid meteor shower isn't always the most prolific, it ranks among the most famous because it occurs during the balmy nights of August. This year, peak activity comes August 11/12, but expect significant activity the next night as well. The shower's radiant — the point from which the meteors appear to emanate — lies in Perseus a few degrees northeast of the Double Cluster. It rises to a decent altitude in the northeast by midnight but climbs still higher in the hours before dawn. The Moon is just past its First Quarter phase and sets before midnight, so dark skies should prevail for this steady annual shower.

Observers who venture to a dark site can expect to see an average of one meteor per minute in the early morning hours. (The key word here is "average" — you could go 10 minutes with no meteors and then see 20 in the next 10 minutes.) Certainly, the Perseids rank among the best showers of any year, and this year, they bring the added benefit of a moonless sky. Next year, a nearly Full Moon will spoil the view, so make the most of this summer's fine display.




ASTRONOMY: ROEN KELLY

**PERSEID METEORS will peak the night of August 11/12, when observers at dark sites should see about one meteor per minute.**

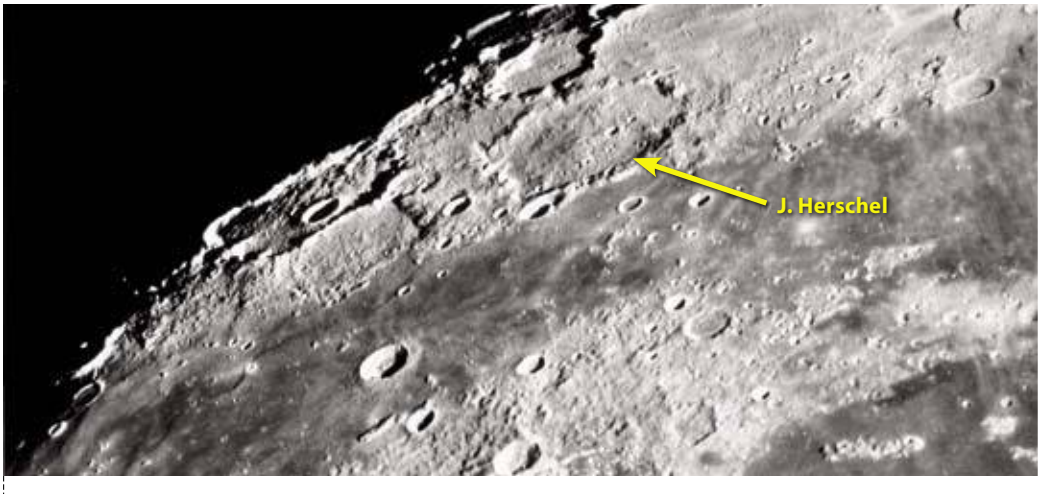
## Herschel's landmark

Few families have the astronomical pedigree of the Herschels. William (1738–1822), who discovered the planet Uranus in 1781, his sister Caroline (1750–1848), and his son John (1792–1871), were all talented observers and telescope-makers. And each is honored with a crater on the Moon.

Lunar cartographers, however, seemed to have a marked preference for William. His prominent crater lies near the center of the Moon's disk. Caroline's diminutive crater resides in northwestern Mare Imbrium, while John's — our feature highlight this month — lies near the Moon's northwestern limb. This poorly defined crater sits adjacent to Mare Frigoris. Lunar libration tilts this region slightly toward our view during mid-August, making it particularly well-placed.

On August 16 and 17, the Sun rises over this area north of the well-known feature Sinus Iridium. A prominent double crater on J. Herschel's southwestern wall runs into Mare Frigoris. A linear wall or ridge runs from this crater pair to the northwest, creating J. Herschel's western boundary.

Inside J. Herschel's 97-mile-wide polygonal wall lies a complex region of hills and small craters. The largest of these craters lies at the center. North of J. Herschel you should see two other craters: 37-mile-wide Carpenter and the adjacent 42-mile-wide Anaximander. Pythagoras is the name of the prominent crater located west of J. Herschel and closer to the limb. Pythagoras' central peak dominates this crater's center.




FROM CONSOLIDATED LUNAR ATLAS (LPL/UA)

**LUNAR CRATER J. HERSCHEL, a nearly 100-mile-wide feature close to the Moon's northwestern limb, has walls degraded by eons of battering and flooding.**

# COMETS AND ASTEROIDS

Comet 9P/Tempel 1 will captivate curious onlookers following its July 4 collision with Deep Impact, but 161P/Hartley-IRAS could be brighter.

## Through the Big Dipper

Periodic comet 161P/Hartley-IRAS slices through the Big Dipper asterism in Ursa Major, putting it on display all night. This is the comet's first return since its discovery 21 years ago. Although some sources expect it to brighten to 8th magnitude, making it just visible through binoculars from a dark-sky site, others suggest a fainter appearance at 11th magnitude.

Astronomers usually give a comet's total magnitude, in other words, how bright it would appear if all its light were scrunched into a point. Start at, say, 10th magnitude, which would be easy to see as a point source through a backyard scope. Now spread the light out into a diffuse disk, and it behaves more like a galaxy and can disappear behind the veil of city light pollution.

To find Hartley-IRAS, head for the country at either the beginning or end of the month, when moonlight isn't a problem. Star-hop your way to its location with the help of the finder chart at upper right. Don't use a bright flashlight — it will compromise your dark adaption. Smaller comets often are not visible immediately at low power, so try something close to 100x.

## Tempel 1's new jet

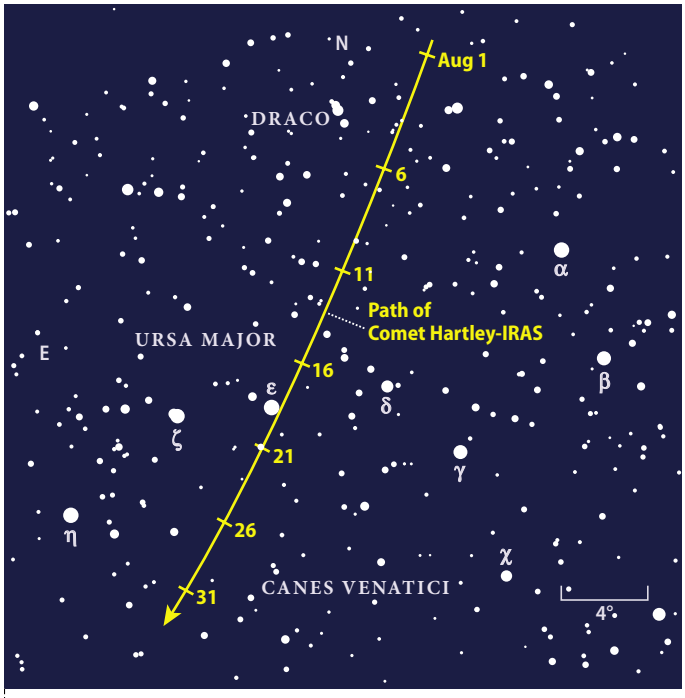
If everything went as planned with the Deep Impact mission last month, the new crater blasted in Comet 9P/Tempel 1 will be producing a jet every time it rotates into sunlight. You'll need to observe from a dark site with at least a 4-inch scope. The best views will come between July 29 and August 8, when the Moon is out of the evening sky. Because no one has ever punched a comet in the face before, we won't know if the impact created a bright new jet unless we look.

While you're in Libra, swing your scope over to globular cluster NGC 5897. It's a modestly large but diffuse object easily hidden by poor sky conditions. Its brightest stars crest at 13th magnitude, so you'll need a 10-inch scope at medium to high power to begin to resolve it into hundreds of faint speckles.

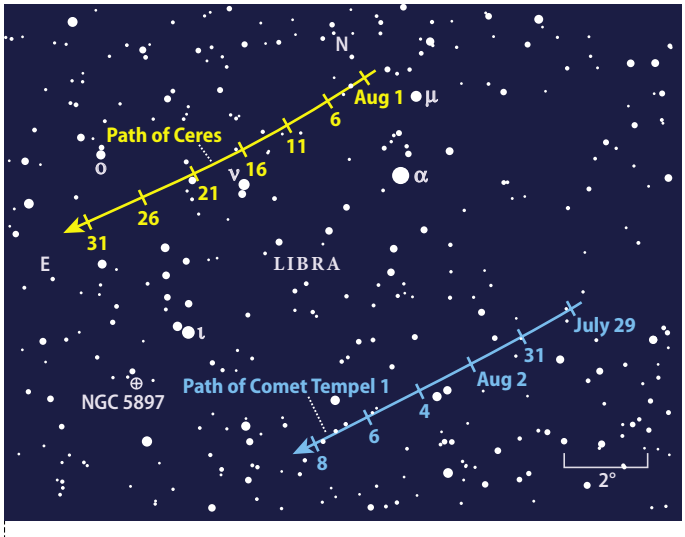
## Subtle Ceres

Despite its large size (595 miles in diameter), Ceres looks like an ordinary field star glowing at magnitude 8.6 when it lies more than 200 million miles away. You can find it the same way its discoverer, Giuseppe Piazzi, did January 1, 1801: by noting its displacement against the starry background.

Ceres moves about 15' per night, half the apparent diameter of the Moon. To see it shift during one evening's session, try observing the night of August 4 or 13. Each of those nights, it lies near several stars that can serve as markers. Come back after an hour or 2 to spot a change in position.




**COMET 161P/HARTLEY-IRAS** skirts through the Big Dipper this month, placing it on fine display throughout nighttime hours.




**COMET 9P/TEMPEL 1,** recently hit by the Deep Impact spacecraft and possibly still brighter than normal, joins the asteroid Ceres in western Libra during the first part of August.

In southern Ophiuchus, dark nebulae serve as backdrops for many globular clusters. /// BY ALAN WHITMAN

# Jewels on velvet

**Globular star clusters and dark nebulae are two of my favorite types of deep-sky objects. Although only about 150 globulars — clusters of 100,000 or so stars — orbit our Milky Way Galaxy, their striking "star ball" appearance puts them among the first deep-sky objects amateur observers turn to. ☾ Dark nebulae are globulars' opposite in every way. Dark nebulae are not collections of stars, but clouds of gas and dust. They emit no light of their own, but reveal their presence by obscuring the glow of more distant objects.**

Astronomers have cataloged hundreds of these dark clouds, which lie mostly in the gas- and dust-rich plane of the Milky Way. Under dark skies with good seeing conditions, many can be seen with the naked eye as apparent holes and tears within the Milky Way's diffuse band. Yerkes Observatory astronomer E. E. Barnard cataloged these objects for his *Photographic Atlas of Selected Regions of the Milky Way*, published in 1927.

## Serpent-bearer synergy

In southwestern Ophiuchus, these disparate objects come together in a wonderful play of light and shadow. Ten globulars — M19 and nine NGC objects — form a rough Y across the dark Pipe Nebula. Full appreciation of these objects requires traveling south, where the southern constellations appear higher in the sky and are better placed for observing.

In his classic guidebook, *Astronomical Objects for Southern Telescopes* (1968), Ernst Hartung reported partially resolving stars in several of these clusters — NGC 6235, NGC 6284, NGC 6293, and perhaps NGC 6355 — with an 8-inch scope in Australia.

However, I usually observe from British Columbia, near 49° north latitude. Most of these clusters barely reach altitudes of 20° above my horizon. What would I see? I decided to find out.

With an 8-inch f/6 Newtonian, I was able to find all the NGC clusters, but only a few showed any detail, and none was resolved from my home observing site. On rare nights, when the sky transparency and seeing were both excellent, my 16-inch f/4.5 Newtonian resolved the two northernmost globulars, NGC 6235 and 6325. Even so, both clusters are so low in the sky that the observatory wall blocks about 35 percent of the telescope's mirror, effectively reducing it to an aperture of 13 inches.

Here's how these circumstances affected my view of the 10th-magnitude globular **NGC 6235**. Hartung writes that, from southern Australia, where the cluster culminates near the zenith, an

ASTRONOMY: KELLIE JAEGER
JEFF BALL

**GLOBULAR CLUSTERS AND DARK CLOUDS** in southwestern Ophiuchus challenge your observing mettle. This plot shows prominent dark nebulae and, with the exceptions of Palomar 6 and NGC 6235, all clusters discussed in this article. North is at top; east is at left.

**THE PIPE NEBULA** and surrounding dark clouds together form a naked-eye feature many observers call the Prancing Horse Nebula, seen here on its tail. The Pipe Nebula, formally cataloged as LDN 1773, spans about 7° in our sky and is about 100 light-years long.

**MESSIER 19,** which shines at magnitude 7, is the brighcest glob lar n this region. A relatively modest scope can resolve its stars at low power. The cluster looks nota- bl oval and shows o sharp rise in star concentration at its center.

DIGITIZED SKY SURVEY

8-inch scope will reveal some stars, but a 6-inch won't.

## Exploring the region

My view, with the globular at low altitude and a wall partially occulting my 16-inch scope, showed some stars coming and going at 305x, and this loose cluster showed no core. So, my "13-inch" in southwestern Canada matched an 8-inch view from Australia, which I found rather satisfying.

**Alan Whitman** *usually observes amidst the vineyards of British Columbia, but he makes frequent trips to points south.*

Neighboring cluster **NGC 6287** is twice the apparent size and significantly brighter than NGC 6235. At 140x, NGC 6287 shows a slightly granular look and some central condensation. I was able to resolve stars at 203x.

Barnard's dark nebulae abound near NGC 6287. **Barnard 51** (B51) was obvious as a lack of stars, but it was not sharply outlined. I could recognize **B60** and **B246** as subtle thinnings of stars but could not make out any boundaries.

The long arc of **B63** is quite prominent at its starless southwestern end, but it is less obvious at its eastern side because many stars appear scattered across it. The region's dark clouds are sometimes collectively called the Prancing Horse Nebula. The Barnard nebulae mentioned above form the horse's forelegs, while the Pipe Nebula forms its hind legs. Under good sky conditions, try seeing this figure with the unaided eye.

## The view from Down Under

I re-observed the other seven NGC globulars from Australia at a superb dark site on the western edge of Wollemi National Park, about 90 miles (150 kilometers) northwest of Sydney. I was determined to see these clusters at their best, so I viewed them all near the zenith. That meant wrestling the 14.5-inch f/7 Dobsonian I borrowed from my friend, Tony Buckley, into its most reluctant positions while standing three steps up a ladder.

**M19**, about 31,000 light-years away, is much larger and brighter than any of the NGC globulars. Even in British Columbia, my 8-inch partially resolves its stars at 116x. With Tony's 14.5-inch at 322x, M19 appears markedly oblate and shows no central concentration, but short star chains run across the core. M19 resembles the giant Omega Centauri more than any other globular, although it is a pale imitation.

**NGC 6284** is the most distant globular cluster mentioned in this article: 50,000 light-years from the Sun, but only about half that distance to the Milky Way's center. Despite its distance, I could resolve about 25 stars in its outer fringes with the 14.5-inch at 322x.

The brightest stars are in a star chain on the cluster's western side. This globular seems to brighten gradually to a tiny star-like core in its middle.

The next target, **NGC 6293**, shows more detail than any of the NGC globulars discussed here. It's located at the northwestern tip of the Pipe Nebula's stem and glows at magnitude 8.2. My 8-inch revealed a tiny, bright nucleus at 116x, a feature reminiscent of the center of the well-known "core collapse" globular, M15. Through the 14.5-inch at 322x, the cluster's symmetrical halo appeared as a dense cloud of stars, and its well-resolved bright core featured a parade of stars aligned east to west across it.

**NGC 6316** lies on the pipe stem's southern side. At 116x with the 8-inch scope, this cluster showed a small, almost uniform glow, except for a hint of a bright

### /// GLOBULAR CLUSTERS

| name | R.A. | Dec | Si e | Mag. |
|---|---|---|---|---|
| M1 (NGC 62 3) | 17h02.6m | –26°16' | 13.5' | 7.2 |
| GC 6293 | 17h10.2m | –26°35' | 7.9' | 8.2 |
| C 6304 | 17h14.5m | –29°28' | 6.8' | 8.4 |
| NGC 6284 | h7h04.5m | –24°46' | 5.6' | 9.0 |
| tGC 316 | 17h16.6m | –28°08' | 4.9' | 9.0 |
| NGC 62y7 | 17h05.2m | –22°42' | 5.1 | 9.2 |
| NGC 64 1 | 7h38.6m | –23°55' | 5.6' | 9.5 |
| NGC 6355 | 17h24.0m | –26°21' | 5.0' | 9.6 |
| NGC 6235 | 16h53.4m | –/2°11' | 5.0' | 10.2 |
| NGC 63 5 | 17h18.0m | –23°46' | 4.3' | 10.7 |
| Palomar 6 | 17h43.7m | –26°13' | 8.4' | 11.6 |

DIGITIZED SKY SURVEY

**NGC 6325** is the faintest NGC cluster discussed in this article, but its position 0.5° north of Omicron Ophiuchi, a striking double star, helps observers find it.

center. The 14.5-inch clearly revealed a small, bright b t unreso v d o e. Int ncy dust d ms GC 6316 so greatly that this was the only NGC globular I couldn't resolve.

My 8-inch at 50x showed **NGC 6304** to be noticeably larger than NGC 6316, with a definite central condensation. With the 14.5-inch at 322x, in variable seeing, I could resolve NGC 6304's halo — and occasionally its triangular core — despite nearly 2 magnitudes of interstellar absorption. At 81x, I could see the subtle dark nebulae **B245** and **B248**, which lie respectively to the cluster's west and northwest, in the same field of view as the globular. The only part of B248 I detected was the third closest to the cluster.

**NGC 6355**, which resides on the pipe stem's northern edge, showed no central condensation; but when seeing settled down, I could partially resolve the cluster through the 14.5-inch at 322x.

**NGC 6401** is an amorphous cluster dominated by a 12th-magnitude foreground star on its eastern side. Through the 14.5-inch scope at 322x, a few resolved stars appeared as the seeing wavered. At 81x, I could make out three small dark nebulae immediately adjacent to NGC 6401 — **B81**, **B82**, and **B83** — by jiggling the scope.

B81 lies immediately to the cluster's southwest. Using a low-power field centered on NGC 6401, I could see the sharp border of the Pipe Nebula's bowl just beyond B81.

The most interesting was B83, which has a meandering border that evokes the shores of a Canadian lake. Elongated B82, to the north, was the toughest of the three to distinguish. Just beyond B82 is the obvious 0.75°-wide ancy of **B272**.

**NGC 6325** is just 0.5° north of Omicron (o) Ophiuchi, a striking orange-and-green double star. At magnitude 10.7, NGC 6325 is the faintest NGC cluster discussed here. With the 14.5-inch at 136x, the cluster's small fuzzy patch was by no means obvious at first. At 322x, the globular appeared to have a starlike central core and, using averted vision, about 20 halo stars came and went as seeing wavered. The region's dust has dimmed the cluster's stars by almost 3 magnitudes.

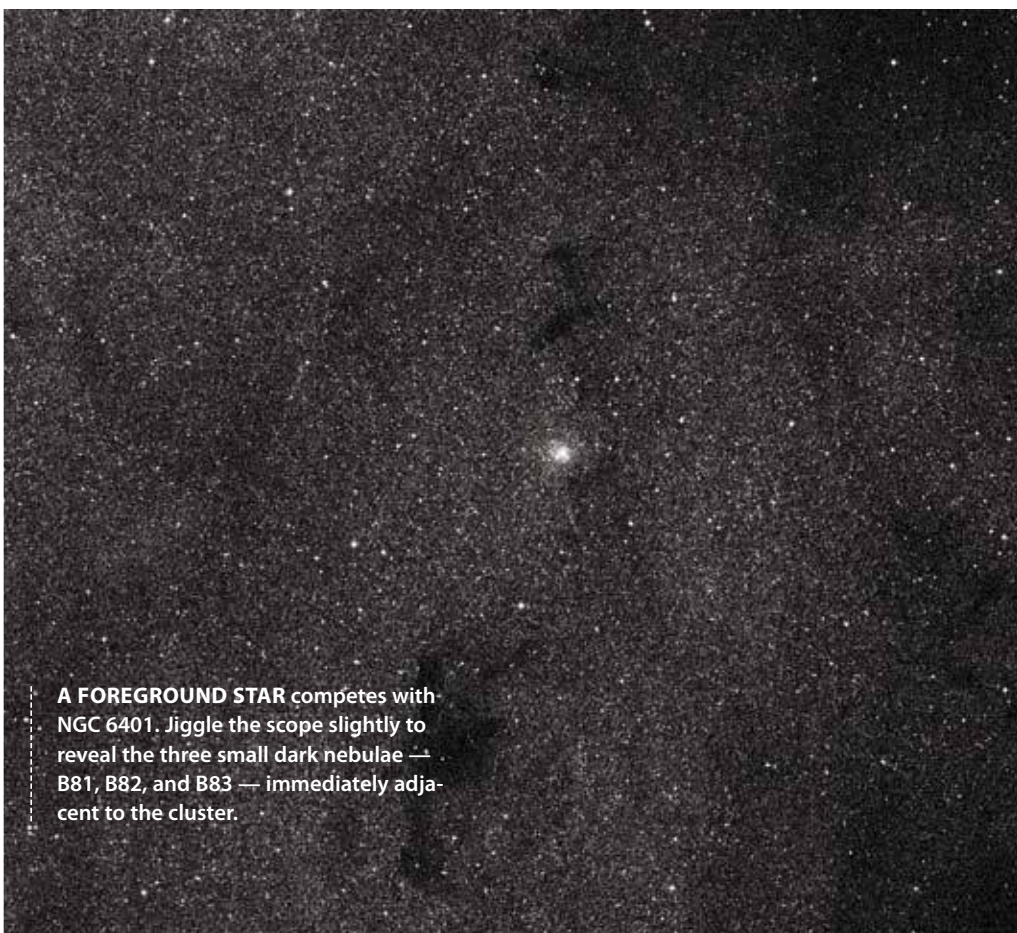
**Palomar 6** (Pal 6) is a true challenge object. It was discovered as part of a photographic sky survey, not by visual observation. Pal 6 boasts a respectable luminosity, with an absolute magnitude of –6.8. At 19,000 light-years distant, it's relatively nearby. For comparison, the globular clusters M30, M56, and M68 have absolute magnitudes of –7.4 and are farther away than Pal 6. The difference is that Pal 6 lies less than 3° from the galactic center, illustrating how severely interstellar dust veils globular clusters near the Pipe Nebula.

Pal 6 is 1° from the Pipe Nebula's black bowl, so star-hopping from the nebula to the cluster involves a lengthy chain. Moreover, observers frequently mistake a nearby unnamed swarm of faint stars for 11th-magnitude Pal 6. In pristine New Mexico skies using Chaco Observatory's 17.5-inch Dobsonian at 133x, I found the real Pal 6 immediately north-northeast of the larger, brighter imposter. The cluster displayed no central condensation and remained unresolved at 222x.

The region's glittering star globes and adjacent smoky dark clouds make wonderful contrasting targets. Take the time to explore this region of Ophiuchus — no matter how well placed it is from your locale. Introduce yourself to a play of galactic light and shadow.

## /// DARK NEBULAE

| Name | R.A. | Dec. |
|---|---|---|
| | **Pipe Nebula** | |
| B59, 65–67 | 17h21m | –26°59.9' |
| B78 | 17h33.0m | –25°59.0' |
| | **Other dark nebulae** | |
| B51 | 17h04.8m | –22°15' |
| B60 | 17h11.9m | –22°26' |
| B63 | 17h16.0m | –21°28' |
| B81 | 17h38.5m | –23°55' |
| B82 | 17h38.6m | –23°46' |
| B83 | 17h39.0m | –24°10' |
| B245 | 17h11.9m | –29°24' |
| B246 | 17h12.0m | –22°39' |
| B248 | 17h13.1m | –28°59' |
| B272 | 17h37.0m | –23°24' |



DIGITIZED SKY SURVEY

**A FOREGROUND STAR** competes with NGC 6401. Jiggle the scope slightly to reveal the three small dark nebulae — B81, B82, and B83 — immediately adjacent to the cluster.

# Ask Astro

Pluto's orbit, more on that equation, floating Saturn

**PLUTO'S ORBIT**

## How close does Pluto's orbit come to Neptune? — RYAN ARNESON, SOUTH JORDAN, UTAH

Looking at a solar system diagram on paper, it appears Pluto and Neptune's orbits intersect. Of course, this is not the case. The orbits appear to intersect only because it's a flat projection, and not the three-dimensional orbits.

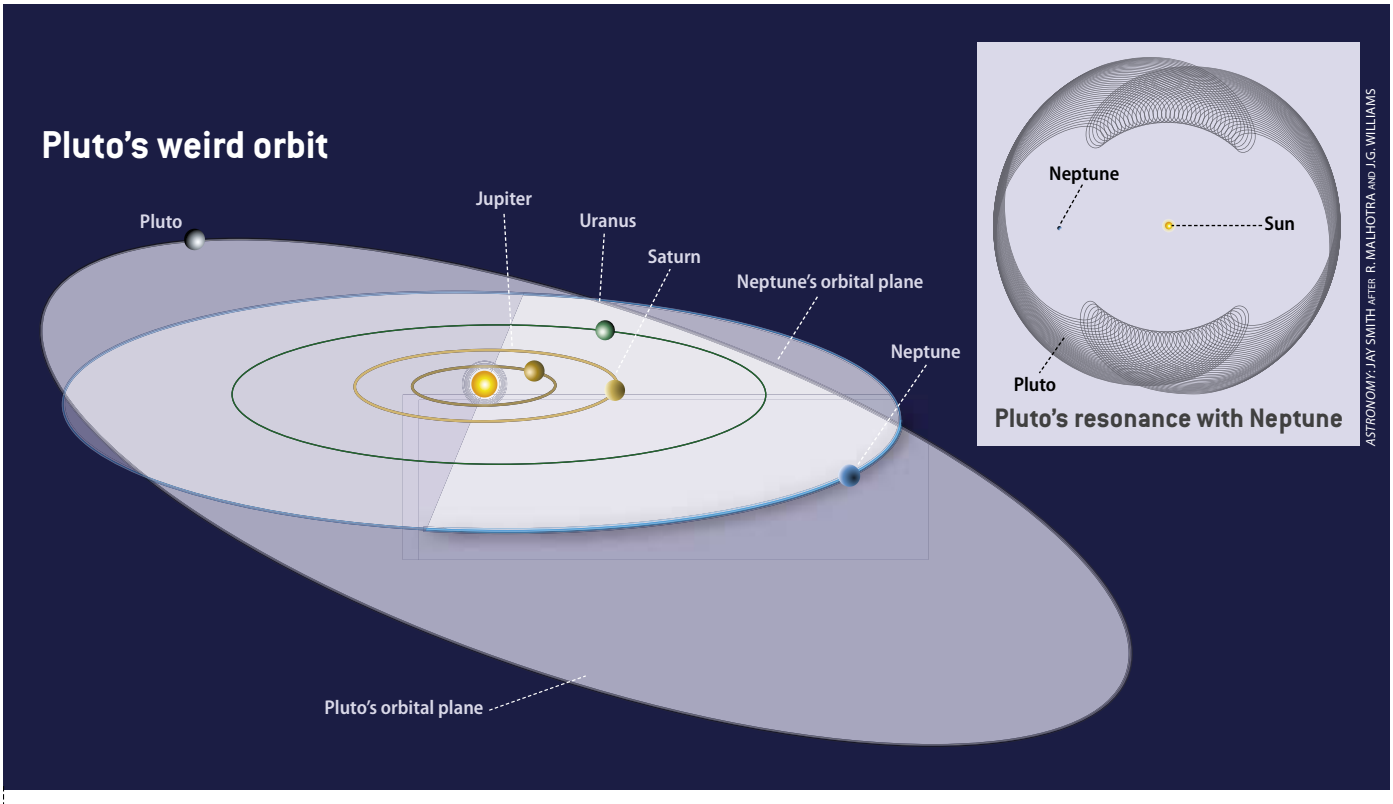
Neptune's orbit is essentially circular and in the same plane as most planets (the ecliptic plane), while Pluto's orbit is elliptical and tilts 17.2° to the ecliptic. So, if Pluto and Neptune were placed on their orbits at the same distance from the Sun, we would find Pluto typically 5 or 6 astronomical units, or AU, above or below the ecliptic (1 AU is the distance between Earth and the Sun).

The closest distance between the two orbits is 2.4 AU. If we could reach out magically and move Pluto and Neptune to any point in their orbits, the closest they could ever get is 2.4 AU. However, this minimum distance can never occur.

Pluto and Neptune have resonant orbits. While Pluto makes two revolutions around the Sun, Neptune makes three; so astronomers say Neptune and Pluto are in a 3:2 resonance. This orbital relationship limits the minimum distance between the planets. They never get closer than about 16 AU.

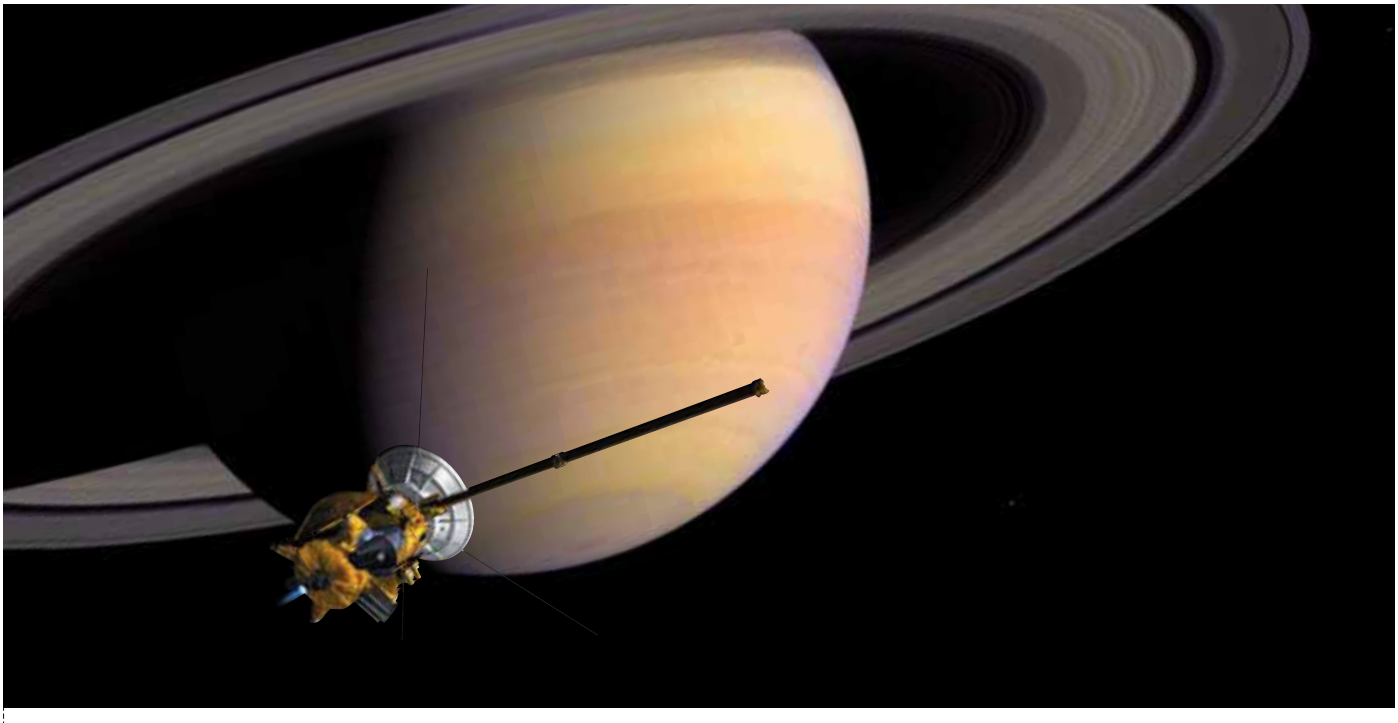
This resonance has kept Pluto from being ejected from the solar system by Neptune's gravity during the past 4.5 billion years. Because Pluto never gets close to Neptune, Neptune's gravity can never alter Pluto's orbit.

Many objects in the outer solar system have resonant orbits with Neptune. About




**PLUTO ORBITS** the Sun twice for every three orbits of Neptune, which, in addition to Pluto's orbital inclination, keeps the two planets at least 16 AU apart. INSET: This simulation of Pluto's motion during thousands of years illustrates its resonance with Neptune. Neptune and the Sun are held fixed in this plot. Pluto carves out a strange, curly path, but never comes close to Neptune.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187.
Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



NASA/JPL/SSI

**CASSINI'S ORBITS around Saturn will help refine our knowledge of Saturn's mass and its internal structure. Astronomers determine Saturn's volume from knowledge of the planet's distance and angular size. Saturn's mass and volume indicate it's less dense than water. In a big enough ocean, Saturn would float.**

70 Kuiper Belt objects (KBOs) also share the 3:2 resonance — these objects are called plutinos — and there are others in different resonances (such as 7:4, 2:1, 5:2). As with Pluto, these resonant orbits protect their inhabitants from being perturbed by Neptune gravitationally. **— LARRY WASSERMAN,** LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA

## MORE ON THAT EQUATION

### I know Einstein's famous equation $E=mc^2$ has to do with energy, but what units are used and what do they mean?

**— GERALD DYCK,** ASSONET, MASSACHUSETTS

Equations in physics and astronomy use the International System of Units, or SI, abbreviated from French. According to SI, the speed of light, *c*, is measured in meters per second, or m/s, as are all velocity measurements. Mass, *m*, is measured in kilograms, or kg. Energy, *E*, is in joules, or J. Joules are a derived SI unit, from base units kg, m, and s. The definition of a joule is $kg\times(m/s)^2$, which is — not surprisingly — the definition of Einstein's famous equation. In more familiar terms, a joule is the work done to produce 1 watt for 1 second.

This equation shows that energy can be converted into mass and vice versa. Keep in mind $c^2$ is a big number. The speed of light is roughly 3 with 8 zeros following it, which means $c^2$ is 9 with 16 zeros following it. So, to convert a small amount of mass — say 1 cubic centimeter of water, equivalent to 1 gram — into energy, divide by 1,000 to make sure you are using kilograms, and multiply by $c^2$. This will give you 90 million million joules of energy, which is equivalent to 25 million kilowatt hours. That's enough electricity to power the average U.S. household for over 2,000 years. **— LIZ KRUESI,** ASSISTANT EDITOR

## FLOATING SATURN

### I've read Saturn is less dense than water. How do scientists know Saturn's mass and volume to figure this out?

**— MARK SHEA,** EAU CLAIRE, WISCONSIN

A planet's mass and volume are easy to determine. Because planets are nearly spheres, we can calculate volume from our knowledge of a planet's radius, which we determine by measuring both the planet's angular size in the sky and its distance.

That takes care of the volume. To determine a planet's mass, astronomers follow the motions of a satellite, either natural or artificial, around the planet. According to Kepler's third law of planetary motion, the sum of the masses of a planet and its satellite relates to the separation between the two bodies and the period of the satellite's orbit around the planet. Thus, to apply this method, we need to find the satellite's separation and orbital period — and this gives us the combined mass of the moon and the planet, not the planet's mass alone.

A better way: Send a space probe, such as Cassini, and measure its distance from the planet and its orbital period as it circles around. Because Cassini's mass is negligible compared to Saturn's, the mass of the planet by itself can be calculated directly using Kepler's third law.

Technically, Kepler's third law assumes the orbits are circular, and we know planets' orbits aren't. However, the mathematical relation one uses for elliptical orbits is a bit more complicated. **— RICHARD CROWE,** UNIVERSITY OF HAWAII, HILO

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>
> **Customer Quote of the Month #161**

## A big 65mm ED astro binocular for only $295.

This 22 x 65mm binocular (designed by renowned refractor creator Thomas M. Back) uses costly low dispersion FPL53 ED glass for a wide 3.5° field virtually free of spurious color. This **TMB**-design bino from **Burgess Optical** is simply the best astronomical binocular value around. Period. And it's the first of a whole series!

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## Get 'em while they're hot – a 2" diagonal for $119.

Some manufacturers charge as much as $250 for a 2" star diagonal with a 97% reflectivity enhanced aluminum mirror and a 1.25" eyepiece adapter.

But the **William Optics** 2" diagonal, with 1/10th wave accuracy and 97% reflectivity, our part #W2, is sale-priced at only **$119**! And that price includes a 1.25" adapter with a non-marring clamp ring eyepiece holder (the 2" eyepiece holder has a clamp ring, too). Quantities are limited at this sale price.

# astronomics

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A few of the TeleVue scopes that we have in stock for immediate shipment are listed below. These are basic optical tubes only, with dust covers and a carry case, for use with your own accessories.

Complete packages for use on your own mount, with a star diagonal, Plössl eyepiece, mounting ring, dust covers, and carry case, are also in stock.

**TV-60,** 2.4" f/6 apo ..... **$795**$^{00}$
**TV-76,** 3" f/6.3 apo ..... **1275**$^{00}$
**TV-85,** 3.35" f/7 apo ..... **1680**$^{00}$
**TV-102,** 4" f/8.6 apo ..... **2200**$^{00}$

## New lower prices on TeleVue light pollution filters.

The high-performance **TeleVue** dielectric narrow-band light pollution filters have dropped in price, but you still get the same outstanding image-improving performance.

Their special red blocking technology and optical quality ground and polished BK-7 substrates allow brighter, sharper star images without the red fringing seen on most light pollution filters.

The UHC-type narrow band filter is good for all nebula types and instrument sizes.

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**UHC,** for 2" eyepieces ..... **185**$^{00}$
**Oxygen III,** for 1.25" eyepieces ..... **95**$^{00}$
**Oxygen III,** for 2" eyepieces ..... **185**$^{00}$

## The $100 Sphinx rebate will soon be gone.

Vixen Star Book hand control showing star chart display

You get a direct-from-Vixen rebate of up to $100 on Vixen accessories when you buy a $2199 **Vixen Sphinx** go-to mount through August 31, 2005. Just buy your Sphinx go-to mount and accessories and send Vixen the invoice. They'll send you back a check for the amount you spent on Vixen accessories, up to a maximum of $100.

The Sphinx Star Book hand control makes go-to astronomy easy. Simply move a cursor to an object on the Star Book's 4096-color LCD star chart screen and the Sphinx moves to that object. That's all it takes to find your way around the sky.

As a Vixen stocking dealer, we keep the Sphinx in stock for use with your own optics, as well as in complete packages using Vixen scopes from a 3.2" refractor up to 8" reflectors and catadioptrics.

**$3299**
ED81SWT-Sphinx 3.2" f/7.7 ED apo Vixen refractor on Sphinx go-to mount

## Inexpensive accessories make your observing easier.

A red flashlight protects your dark-adapted night vision while you are observing. **Celestron's** variable brightness red flashlight (our part #VLED) is **$21.95**. The **Rigel Systems** variable brightness red light shown (our #4591) is **$24.95**. Rigel's 2-color variable brightness light (#4592) – red for reading star charts, blue-white for setting up or taking down your scope – is **$29.95**.

Put vibration suppression pads under the legs of your telescope or spotting scope tripod and you'll virtually end the tremors that blur your view for a few seconds every time a breeze comes up or you touch the scope to focus. A set of three **Celestron** anti-vibration pads (our part #VSP), costs **$49.50.** The **Meade** #895 pads to the right cost **$49.95.** Both sets take the frustration out of observing and are well worth their low cost.

**Celestron Power Tank** rechargeable 12-volt batteries have the power you need to run your scope and accessories all night long. You can recharge them hundreds of times, saving you big bucks over the cost of buying flashlight batteries every few weeks. Each has *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; built-in recharger; shoulder strap; carry handle; and more. The 7 amp hour Power Tank shown, our part #4512V, is only **$59.95**. The 17 amp hour Power Tank, our #4517V, is only **$89.95**.

Setting up your Celestron NexStar or Meade LX200 in the dark can be tricky. It's difficult to line up the mounting holes in the telescope and tripod if you can't see them. The **Landing Pad**, our **$49.95** #LPAD, above, and the **Astroplate**, our #APLATE at **$99**, below, make the job easier. These aluminum plates bolt to your tripod. They have guides that center your telescope to line up the mounting holes precisely. The Landing Pad works with 8" to 11" altazimuth NexStars. The Astroplate works with any 7" through 14" altazimuth LX200. The Astroplate also has a built-in level and will hold your Autostar hand control and up to 11 eyepieces.

Not exactly an inexpensive accessory, but certainly an invaluable one, the **$265 Scopebuggy** scope transporter is so efficient that the 6 year-old daughter of one of our customers moves her Dad's 14" Celestron all by herself. Big 10" pneumatic tires, a pivoting front wheel, and a pull handle make it child's play to move scopes weighing up to 300 lbs. with the new Scopebuggy.

**$265**

## We ship Meade from *our* stock to save you time/money.

Meade 8" LX200 GPS **$2299** *freight paid*

A lot of Meade dealers don't stock Meade telescopes. They have Meade ship them to you. That means you pay sales tax if you live in California.

A California resident doesn't pay sales tax on a 7-10" LX200 or RCX400 shipped from our stock.

And, if a dealer has to order a scope from the factory, it may take days before he even finds out if it's in stock. We can tell you immediately if we have a scope for you, and you won't have to wait extra days for shipment from the factory.

Plus, if you live in the midwest or on the east coast, it often takes an order two to four days longer to arrive when it's shipped from a west coast warehouse than it does when it's shipped from our warehouse in the center of the country.

Here are the *freight-paid* prices for the LX200/RCX400 scopes that we typically ship from our inventory via Fedex ground to the 48 states to save you time and money:

**7" LX200 Maksutov** ..... **$2799**$^{00}$
**7" LX200 Maksutov**, w/UHTC ..... **2949**$^{00}$
**8" LX200 Schmidt** ..... **2299**$^{00}$
**8" LX200 Schmidt**, w/UHTC ..... **2474**$^{00}$
**10" LX200 Schmidt** ..... **2999**$^{00}$
**10" LX200 Schmidt**, w/UHTC ..... **3234**$^{00}$
**10" RCX400** Ritchey-Chrétien, UHTC .. **5149**$^{00}$

## We're your Meade Tier 1 stocking dealer . . . get accessories fast from www.astronomics.com/meade.

Being a Meade Tier 1 stocking dealer means we keep most Meade scopes and accessories in stock in our own seven-figure inventory. You don't have to wait days for your local dealer to have Meade ship a scope or accessory to you. In many cases, we ship from our stock, usually saving you time and money – and in most cases saving you the sales tax. Visit our website for fast shipping.

## Meade Deep Sky Imager Pro, $499.

MEADE Tier 1 Stocking Dealer

The **Meade Deep Sky Imager Pro** takes monochrome astronomical photos for only $399 – a fraction the cost of a CCD camera. Buy the camera/color filter package shown at $499 and it takes tri-color images as well. Works with any telescope, but you can use its NASA-developed "Drizzle" software with Meade Autostar-equipped ETX, LX90, LX200, or RCX400 scopes to take images up to 4.9 megapixels in size.

## Meade LX90-LNT – new 8", 10", and 12" scopes.

The best-selling **Meade LX90-LNT** 8" has been joined by 10" and 12" models. The 8" and 10" scopes ship from our stock, so we save you shipping time over dealers who must have them drop-shipped from Meade (and if you're in California, we save you the sales tax).

Here are the *freight-paid* prices on the LX90's shipped from our stock:

**8" LX90-LNT** ..... **$1799**$^{00}$
**8" LX90-LNT,** w/UHTC ..... **1974**$^{00}$
**10" LX90-LNT** ..... **2299**$^{00}$
**10" LX90-LNT,** w/UHTC ..... **2474**$^{00}$

For 12" LX90's shipped from Meade:

**12" LX90-LNT** ..... **$2999**$^{00}$
**12" LX90-LNT,** w/UHTC ..... **3294**$^{00}$

*Level North Technology* makes it easier to line up your scope on the sky. Simply tell an LX90-LNT your location *or zip code.* It levels its optical tube by itself, aims it north, sets the time, and moves to its alignment stars – *automatically!* Center the red dot finder on the alignment stars (you get an 8 x 50mm finder, too), and start go-to computerized observing. The LX90 is an *easy* scope to use, and now comes in large economy sizes!

Meade 8" LX90-LNT **$1799** *freight paid*

## New Meade accessory packages save you a third.

Meade has combined popular ETX, LXD75, LX90, LX200, and RCX400 accessories into packages that cost a third less than buying the items separately.

Five ETX kits for terrestrial and astronomical observing and astrophotography start at $99. Three LXD75 kits for observing and astrophotography start at $199. An LX90 astrophotography kit is $249. And two LX200/RCX400 kits for astrophotography start at $349.

Full details on the contents of the kits and the big bucks you save on each are at **www.astronomics.com/meade**.

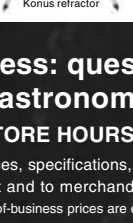
## Are these great values? You bet they are.

The low prices of these **Konus** telescopes are downright amazing.

Consider the 90mm **Konusmotor-90** f/11 refractor, left. It has a good equatorial mount, a battery-operated motor drive, *two* 1.25" Plössl eyepieces – and it's value-priced at only $209!

The **Konusky-200** 8" f/5 reflector, right, has a heavy duty equatorial mount with steel leg tripod, *dual-axis* drives, *two* 1.25" Plössl eyepieces, a big 8 x 50mm finderscope, a polar axis finder – and it's value-priced at only $519!

The **Motormax-150** 6" Maksutov, right, has the same big mount and accessories as the 8" reflector – but it's value-priced at a low $799, well below other Maks.


**$209**
3.5" f/11 Konus refractor

**$519**
8" f/5 Konus reflector

**$799**
6" f/12 Konus Maksutov

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The year's best meteor shower arrives this month. /// BY MIKE REYNOLDS

# Star shower

## During August's second week, you'll

read about it in your newspaper or hear it discussed briefly on radio or television: The Perseid meteor shower is coming. Here's the whole story.

### A quick look ahead

Whether this is your first — or 25th — time observing the Perseids, it will be a good shower, unless poor weather becomes your nemesis. The First Quarter Moon will set around 1 A.M. — just as the Perseids are hitting their stride (the shower is best after midnight). The Moon will not interfere with the shower's peak, on the evening of August 12 or the morning of August 13. The timing also is terrific: The peak occurs on a Friday night and Saturday morning; perfect for those who work or go to school.

### Meteors 101

First-time meteor observers need a few simple definitions. A meteor is a streak of light usually seen at night. Meteors — often called falling or shooting stars — are pieces of comet dust that strike our atmosphere at speeds between 36,000 and 150,000 mph. We see them as momentary light streaks as friction with the air vaporizes them. In space, the particles are called meteoroids. If a meteoroid is large enough, it may survive its fiery voyage through Earth's atmosphere. Once it's on the ground, the piece of rock or metal is called a meteorite. However, neither the Perseids nor any other meteor shower produces meteorites — the particles just aren't large or strong enough.

Because meteors from this August shower appear to radiate from an area within the constellation Perseus, astronomers named it the Perseids. All meteor showers are named for a constellation or a bright star within a constellation. Thus, the November Leonids radiate from Leo, the December Geminids from Gemini, and the Delta Aquarids in late July and early August from a spot near the star Delta (δ) Aquarii. And the sources of meteor showers — with two possible exceptions — are comets.

### Perseid history

The passage of Comet 109P/Swift-Tuttle, which last swung through our part of the solar system in 1992, created the Perseid meteor shower. Swift-Tuttle's orbit takes it around the Sun every 130 years.

Astronomers didn't recognize this now-famous annual shower prior to 1834. John Locke, the headmaster of a Cincinnati girls' school, noted the meteor shower in 1834 and defined its radiant in Perseus. The same year, Adolphe Quételet, a Belgian who directed the Brussels Observatory, first noted increased meteor activity in August. In 1837, Edward Herrick, a bookstore owner in New Haven, Connecticut, noticed the Perseids. In an 1838 paper, he stated the shower had been known for some time.

Egyptian observations of the Perseids date back to 1029 B.C. Chinese references to it date back to A.D. 36. The Perseids also are known as the tears of Saint Lawrence, who was martyred August 10, 258. The meteor shower, which peaks near this date each year, represents his suffering.

### Collision course

During its orbit around the Sun, Earth occasionally passes through dust streams left behind by comets. All but two meteor showers originate with comets. The exceptions — the Geminids and Quadrantids — are associated with the asteroids 3200 Phaeton and 2003 EH1, respectively.

The intersection of a meteoroid stream and Earth produces multiple meteors, thus a meteor shower. The shower's radiant, or the meteors' apparent origin, is in a general area in the sky, not a specific point in space. The radiant also tends to drift from night to night, so tracking the radiant also is a good project. To do this, carefully draw the location of shower meteors on a star chart during several nights, then trace their paths back to a general area in space.

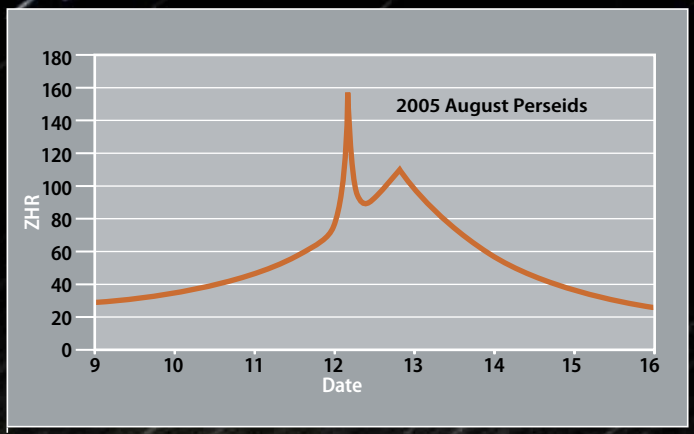
Shower meteors radiate from a general area because of perspective. The streams of meteoroids travel through space in parallel orbits. As Earth crosses the streams, the

MICHAEL E. BACKICH

### /// WANT MORE METEORS?

Other meteor showers are active at the same time as the Perseids. Even though their contribution is comparatively small, more meteors make for a better display overall.

| Shower name | Active dates | Peak | Maximum hourly rate |
|---|---|---|---|
| Southern Delta Aquarids | July 12–Aug. 19 | July 28 | 20 |
| Southern Iota Aquarids | July 25–Aug. 15 | Aug. 4 | 2 |
| Northern Delta Aquarids | July 15–Aug. 25 | Aug. 8 | 4 |
| Kappa Cygnids | Aug. 3–25 | Aug. 17 | 3 |
| Northern Iota Aquarids | Aug. 11–31 | Aug. 19 | 3 |




DATA COURTESY BILL COOKE, MSFC

**WHAT IF THE WEATHER'S POOR** at your location or you'd like to observe on another night? The Perseids are active from around July 17 until August 24. This graph shows the projected activity for a 1-week period centered on the 2005 Perseids' peak. ZHR numbers refer to an idealized meteor count at a true-dark site with no clouds and where the radiant is at the zenith (directly overhead). ZHR, therefore, is not the count you should expect, but rather a meteor activity gauge for this year's Perseids.

**THIS PERSEID** plunged through the summer Milky Way in Cygnus the Swan August 12, 1991. The bright streak to the left of center is Deneb (Alpha [$\alpha$] Cygni]. To its lower left, the North America Nebula (NGC 7000) is visible.

## PHOTOGRAPHING METEORS

e eor pho ography is usually done unguided, with the camer ( m tal SLR) on fixed ripod. You course, guid the camera by attaching it to an qu tor ll unted telescope at go-to scope on an alt-azimuth mou t w ll rotate the f eld of vi during the expo sure, producing "stepped" star images.) Here a me recommendations for pho tographing meteors:

- Keep an ac rate cor of exposure t mes nd dur t ons, and also the coordi nates f t image's center. You should b ab entify a lea t six stars in the image.
- For tripod-mounted shots, keep the exposures between 5 and 15 minutes to reduce star trailing. If there is an exceptional rate of meteoric activity, keep all exposures to 5 minutes.
- With a digital camera, you can take a darge number of short exposures (15 to of 30 seconds) that will maintain stars as points of light. By adding the appropriate software, you can later stack as many of these images as it takes to bring out the background stars. Set your digital camera's ISO setting to at least 800.
- Aim the camera between 50° and 70° above the horizon so the largest portion of sky is within the field of view. Aim your camera about 30° from the radiant. Most meteors don't become visible until they have traveled some distance from the radiant.
- Align your camera so that a meteor coming from the radiant will travel parallel to the short axis of the frame. If the long axis is parallel to the meteors, you'll image fewer of them.
- Keep a careful record of your images. If you have prints made, be sure to make them at least 5" by 7". Include all edges of the negative in your print, and make the print lighter than normal to catch fainter meteors.
- Some advanced meteor photographers have made rotating shutters that are placed in front of the camera lens. These relatively simple devices resemble a two-bladed fan, with each blade slightly larger than the camera's lens. When a bright meteor passes through the field of view, the meteor image is "chopped." From this, it is possible to compute the meteor's duration within 1/10,000 of a second. Divide the revolutions per second (times two shutter blades) into the number of meteor breaks. Motors used for this purpose turn at about 1,000 rpm.

*— Michael E. Bakich*

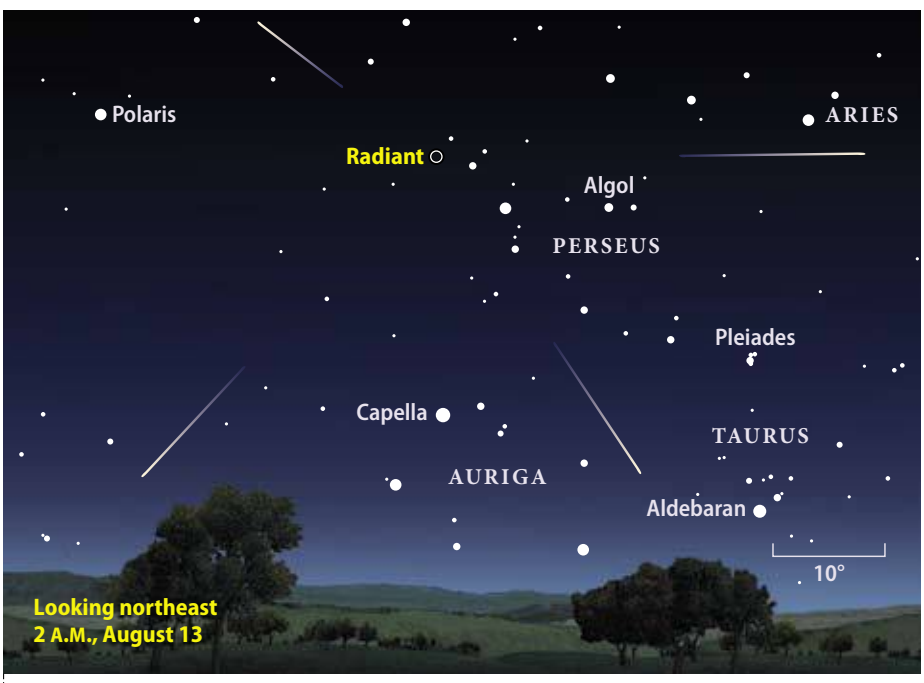
trails of any two meteors appear to converge on the radiant, just as railroad track rails seem to converge on a distant point.

### How many and when?

The number of meteors you can expect to see during a meteor shower differs a bit from the published rate. Astronomers typically rate the Perseids at, say, 100 meteors per hour. This number is the Zenithal Hourly Rate (ZHR) and is based on the number of meteors an observer could see under ideal conditions. By "ideal," astronomers mean the shower's radiant is directly overhead; the sky is clear; and no moonlight or artificial light interferes with observing. Meteor observers rarely achieve a rate equal to the ZHR.

Perseid meteors tend to be bright and fast, with occasional fireballs. A "fireball" is a meteor bright enough to cast a shadow, which typically means it's brighter than the planet Venus (magnitude –4.4). Fireballs can last several seconds as they make their pyrotechnic entry through the atmosphere. They can rival the Full Moon — and even the Sun — in brightness, and can be seen even during the daytime. Fireballs also tend to leave a smoke trail, called a train; but regular meteors also can leave trains. Meteor trains can last seconds or even minutes.

Tables listing annual meteor showers provide the date of each shower's peak. But meteors from a particular shower can often be seen for days (and sometimes weeks) on either side of the peak date. You'll see fewer meteors than at the peak, but you'll see more than the number of




STEVE ONOMOEN KELLY

**THE RADIANT** of the Perseid meteor show r lies a bit more than 3° from 2.9-magnitude Gamma (γ) Persei. Fo t su , focus your view roughly 30° from the radiant.

**Mike Reynolds** *is a college astronomy professor and has written several astronomy books, including* Falling Stars, *a book about meteors and meteorites.*

random or sporadic meteors, which averages about 7 per hour.

## Observing the Perseids

Meteor watching is considered by some to be the most romantic of all astronomical endeavors. It requires the least equipment and the least knowledge of the night sky. Meteor watching is a great way to introduce beginners to the constellations, star identification, and magnitudes. You can do it alone or as part of a group. And observing during an active meteor shower — like this year's Perseids — is thrilling.

Meteor observing is simple: Just look up. You'll need patience, especially if the meteor count is low or the weather is poor. To make the experience enjoyable, I recommend a fully reclining lawn chair with an adjustable back. Don't use a regular chair; you'll strain your neck looking up and around. Some observers use pillows or cushions on their lawn chairs for additional comfort. Lying on the ground is not recommended, even in a sleeping bag — you'll lose lots of body heat — neither is standing for an extended period of time, because you'll become fatigued.

A blanket or sleeping bag will keep you comfortable. Even during summer nights, a sleeping bag is useful for padding the recliner, helping to keep mosquitoes at bay, or for keeping warm during cool mornings in some parts of the country.

The quickest way to end a meteor-watching session is to be dressed too light for cold weather. Remember, when you're watching meteors, your body is immobile and not generating heat through exercise. Even though the Perseids peak in August, nights can be cool. Dress in layers. You can peel off clothes as needed.

Some areas require the use of insect repellant. Mosquitoes can ruin a night of meteor watching by becoming an intolerable nuisance.

A thermos of a favorite beverage can make observing more enjoyable, especially after midnight. Bring along some light snacks if you like, but don't eat too much — that will make you sleepy.

Some observers record specific information, such as hourly counts of shower and sporadic meteors. Recording supplies can include a clipboard, pen or pencil, meteor observing forms, and a red-filtered flashlight. You may need a tape recorder if you're recording specifics such as hourly counts, the time you see each Perseid or sporadic meteor, its brightness, and whether it leaves a train.

All flashlights must either emit red light or have a red filter over the front lens. Unfiltered light ruins night vision. Point the light down — if someone is photographing meteors, light will "fog" the film.

One optional item is binoculars. For normal meteor observing, binoculars limit your field of view, but close-up views of meteor trains provide a nice break.

Finally, try to observe from a dark site. Perhaps your local astronomy club, science center, or planetarium has made arrangements to observe at a city or state park. Getting away from city lights will make a big difference

### /// QUICK OBSERVING TIPS

Meteor Natc ing is fun for Mot individEals andO roups. To get more out of it, follo the tips listed here.

- Look about two-thirds of the way from the horizon to the zenith. Don't place the radiant in the center of your field of view.
- Find the radiant on the chart on page 72 and, when darkness falls at the site, find that position in the sky and memorize it.
- Every observer in a group should observe independently. Never try to combine data from different observers.
- Always note the site's limiting magnitude — the magnitude of the faintest star near the zenith (overhead) you can detect. Limiting magnitude is different for each observer. It defines both sky conditions and the quality of your eyes.
- Shower meteors appear faster the greater their distance from the radiant (up to 90°) and the higher their elevation above the horizon. Near the radiant or near the horizon, shower meteors appear slower.
- Don't look at constellation figures. Try to see only a random collection of stars, and don't concentrate on the stars. Watch the overall area, not individual points of light.
- If you choose to record your observations, use a tape recorder or write on paper. Don't take your eyes off the sky. Using paper takes practice. Your notes should include:

1) Start and end times of the meteor watch, noting all breaks

2) Limiting magnitude and any changes to it during your watch

3) Details of any cloud cover present

4) The R.A. and Dec. of the center of your field of view

5) Details of all meteors observed (magnitude; whether it was a Perseid or a sporadic; train; color)

6) Unless you're going to photograph meteors, or a fireball appears, the time of individual meteors is of little interest. Enter the time in your notes every 30 minutes or so. So-called burst rates (high numbers of meteors during short periods of time) have been reported recently by some observers. Burst rates are worthless in the calculation of ZHR but may be useful in determining maximum meteor activity if the length of the shower's peak is short.

## This year's Perseids

With the Mo n as a non-fQct , this should be a good ear f r the erse ds. StarN observing around 10P.M. local time. The best rates occur after midnight, as Perseus (the shower's radiant) rises higher in the sky. I like to face northeast; other observers prefer the north or the east. Wherever you look, make certain you have a clear horizon, with no trees, houses, or hills blocking your view. Concentrate on an area halfway up in the sky. If your observing time is limited, I recommend the few hours prior to sunrise.

Now it's up to you to record part of this year's Perseids history. Remember, your answer to "What did the Perseids look like in 2005?" will be different than anyone else's. Be comfortable, observe carefully, but above all, have a great time.

Producing high-quality astroimages takes practice. Here are some hard-won lessons I've learned along the way. /// TEXT and IMAGES BY BRIAN LULA

# Image like a pro

## The biggest challenge in digital

astrophotography is making the best images with the tools we have. There's a lot of luck involved in good imaging, but an astroimager who is prepared will have the best luck. Consider some of the things that have to work in concert during an imaging session: good weather; good seeing conditions; neighbors' cooperation by turning off outside lights; and, of course, equipment condition and quality.

### Advanced beginnings

The starting point is equipment. Besides good optics, everything should be rigid and able to hold alignment over long time periods wherever you point the tube. Polar align the mount carefully, and work hard to eliminate backlash in the drive.

What's next? Well, we have to find suitable guide stars, control filter wheels, take calibration images, find the best focus (and monitor it), and avoid computer glitches or power interruptions during the imaging run. Whew! When I add the variables of wind, clouds, changing temperatures, and dew, I sometimes feel like I'm locked in the combat of machine versus nature. But the colorful images that reveal our universe's incomparable beauty and complexity make it all worthwhile.

### Enter my world

It may sound daunting, but these technical challenges are driving forces behind my lifelong interest in telescope-making and digital imaging. As my experience with CCD imaging grew, so did the demands it placed on my equipment.

I enjoy building scopes as much as using them. Building is less expensive if you have the skills to do the machining or woodworking yourself and can locate inexpensive, quality components such as motors, gears, or raw materials. Obtaining the best performance from homemade equipment though, is difficult. If something isn't working right, you have to find the problem and fix it. On the other hand, it's exhilarating when things work just as you planned.

My interest in astronomy goes back to 1960, when I was 5 years old. My dad took me outside to watch the satellite Echo 1 pass overhead. From that moment, I was hooked. As my interest grew, I read every book our local library had about stars and

**THE AUTHOR stands ready to image a distant nebula or galaxy with his 20-inch RC Optical Systems Ritchey-Chrétien reflector in his backyard observatory.**

**NGC 891'S FIELD shows one big, beautiful spiral galaxy and many fainter galaxies. The total exposure time was 236 minutes; each individual image was a 4-minute exposure.**

**VAN DEN BERGH 142 is a combination emission and dark nebula complex in Cepheus. This image is HαRGB with exposure times of 60, 30, 30, and 30 minutes, respectively. Individual exposures were each 3 minutes long. Lula used his 20-inch Newtonian reflector and a Finger Lakes Instrumentation IMG6303E CCD camera.**

**THE CRAB NEBULA** (M1), a supernova remnant in Taurus, is a favorite target for astroimagers, but few have recorded such subtle details in the object. The author used his 20-inch RC Optical Systems Ritchey-Chrétien reflector and an FLI IMG6303E CCD camera to produce this LRGB image. Exposures were 60, 20, 20, and 20 minutes, respectively.

**FROM HUMBLE BEGINNINGS,** the author has made great strides in imaging. He created this 1998 image of spiral galaxy M66 in Leo with a 12-inch Newtonian reflector and a home-built Cookbook CCD camera. Compare it to the Crab Nebula image to its left. Note the difference in resolution and the level of subtle detail between the two images.

**SHARPLESS 2–101** in Cygnus shows a combination of emissioY and dark nebulosity. The author used his 20-inch RC Optical S stems Ritche - h tien telescope and a Finger Lakes Instrumentation (FLI) IMG6303E CCD camera. This i an RGB image with total exposure times of 180, 45, 30, and 30 minutes, respectively. Hα individual exposures were 10 minutes, while the RGBs were 3 minute8.

telescopes, but telescopes themselves always held the highest allure.

When I entered high school, I determined the only way to get a good scope was to make one, and what better place to learn how? I took mechanical drafting and machine shop courses, and before long I was making parts for my own scopes.

In college, all my projects were centered on telescope-making. I designed and built a mirror-grinding machine, then ground and polished a 12½-inch f/6 mirror. I then designed and built a motor-driven equatorial fork mount. The reward came at the end of each year, when I could buy my project cheaply from the school. The result was a sizable and robust telescope.

## The fruit of my labor

Nothing, however, teaches you the shortcomings of a telescope or mount like using it. In the early 1980s, I did some time-exposure photography on Kodak Tri-X film. The overall precision of my design and craftsmanship was less than I expected — a humbling experience after I had invested so much time and effort in building the telescope. These lessons, though, were invaluable. As I designed and built other telescopes, each one performed better than the one before.

I began CCD imaging in 1995 after I built a Cookbook 245 camera. My skills in electronics are weak, so I carefully followed the circuit designs step by step. I was impressed with the author's instructions and soon finished the circuit boards. Because I was more familiar with the mechanical design, I made a few changes to match the camera to the telescope better. When finished, the camera performed flawlessly.

I'll never forget my first CCD image. I mounted a 2-inch achromatic lens on the front of the Cookbook camera and pointed it skyward through a window for a 60-second exposure of the summer Milky Way. It recorded so many stars and faint nebulae that I thought something went wrong. Next, I hooked the camera to my 12½-inch Cassegrain and imaged the Dumbbell Nebula (M27). When I saw that image, I knew my astronomy experience would forever change from visual observing to imaging.

Since then, my CCD imaging goals have evolved to high-resolution, wide-field color images. I have a particular interest in galactic nebulae. Writing this article made me go back to my earliest photography days and pull images chronologically, which showed my progress during the last 10 years. Because I was building scopes and mounts along the way, it was interesting to see how design changes affected image quality.

**RARELY IMAG D GC 712**, a 5emission nebula complex in Ceph1us, includes a star ɛlus ter. The author used his 20-inch RC Opt3cal Systems Ritchey-Chrétien reflector and an SBIG STL-6303E CCD camera to produce this LRGB image. Exposures were 100, 60, 60, and 60 minutes, respectively.

**Brian Lula** *is a lifelong telescope maker and the president of Physik Instrumente USA. He loves to im g deep-sk jects.*

## Lessons

I've learned a lot during the last 10 years. 6rial a d error is indeed necesGa y.

Whe maging faint deep-sky objects, get as long a single exposure as practical. The length will be based on your mount's precision; the amount images bloo Cith your CCD detector; and sky back round.

One of my earliest lessons made a big impact after I built a 20-inch f/5 Newtonian Astrograph. This scope used a moderate-cost Pyrex primary mirror. On some nights, though, the mirror's surface never stabilized due to theD hanging temperature, and, therefore, good images were impossible. I learned imaging with large-aperture telescopes is not tri al, and if you want higher resolution, materials with a low coefficient of thermal expansion are paramount.

An en 6ur?gi6g leEs for small-te escope owners is that with a finely tun d, high q al ty 6- to 8-inch scope, dark skies, good eei g, an exce lent processing ill K youCcan p oduce "giant Gller" images — those that look like they were taken with much larger instruments. Good seeing levels the playing field.

When I started CCD imaging, I thought 20 stacked 30-second images — totaling 10 minutes — were all I needed. Over the years, however, the individual exposures grew to 3 minutes, then 5 minutes, and now 10 to 30 minutes for individual Hydrogen-alpha (Hα) filtered images. The total exposure times have grown from 10 minutes to a minimum of 30 minutes and as much as 8 hours with Hα and other narrow-band filters such as the OIII and Si2. As exposure length grew, image quality improved. I used to acquire five or six tricolor image sets in one all-night session. Now it might take 2 or 3 nights to secure one set of tricolor images.

It helps to oversample your deep-sky images slightly based on your seeing conditions. A few years back, the "sweet spot" for high-resolution, deep-sky imaging was a scale of 2" per pixel. Many imagers experimented with their own techniques and produced even higher-resolution images. They discovered that, as with planetary observing, there were moments the admosphere steadied. With the appropriate pixel scale the CCD would record these high-resolution moments. You couldn't see them in the raw image, but processing exposed the fine details. This leads me to my final observation.

It's one thing to acquire good image data. It's quite another to process it — to find a good balance between aesthetics and technical accuracy. Image processing was a challenge I found hard to learn. Initially, this created a lot of frustration because it required reprocessing the same image many times until it looked right. I actually have spent more time on some images than the time it took me to grind an polish a 6-inch mirror! To this day, my techniques are evolving.

**EVEN WITH A GIBBOUS MOON in the sky, the author creates striking images. This spiral galaxy — IC 342 in Camelopardalis — spans approximately ½°, the same size as the Full Moon, so its surface brightness is low. Lula combined fifty 3-minute exposures through his 20-inch RC Optical Systems Ritchey-Chrétien reflector and FLI IMG6303E CCD camera to create the final image.**

**MOST OF US WOULD LOVE to create an image like this of the Horsehead Nebula (B33) in Orion. The author, however, wasn't satisfied. He made this/his first tri-color image, in 2000 and noticed his CCD chip allowed nasty "blooming" spikes into the image. His lesson: Getting good color is a lot of work.**

A wealth of objects remains uncaptured. You can now go to higher resolution, use bigger CCD cameras, and employ better filters. As you do, your opportunities multiply. So step off the beaten path and seek out new challenges.

**ONLINE EXTRA** To see more Brian Lula celestial images, be sure to log on to www.astronomy.com/toc

**THE MEDUSA NEBULA (ABELL 21) in Gemini offers a tough observing target; it took the author some extra effort to image it. His total exposure time for this HαRGB image was 6 hours: 200 minutes in Hα and a total of 160 minutes in RGB.**

Antique astronomy books are treasures you can collect. /// BY MICHAEL E. BAKICH

# Paging through the past

**I love visiting with Percival Lowell and John Herschel. How? Through books they wrote long ago. Collecting antique astronomy books is easier than you think. And the sooner you start, the more successful you'll be.**

## The observer's era

The standard definition of an antique is "anything more than 100 years old." This definition places me squarely in my main era of astronomy book collecting: the 19th century. More specifically, I collect English-language first editions. One reason for specializing is I don't have the space or money to collect all astronomy books.

Another reason is that the 19th century was an exciting time for astronomy. Great comets crossed the heavens with startling frequency. Neptune was predicted, then discovered. The stars and nebulae of the Southern Hemisphere were studied in detail. Photography and spectroscopy were invented and applied to astronomy.

During the 19th century, a sense of adventure and discovery permeated astronomy. Observers working alone often made important contributions.

Back then, one person could make a difference. Unfortunately, I'll never live in such a time. In my spare time, however, I've created a time warp of sorts — a cherished space where I interact with great astronomers of times past. My books transport me back to the romantic era of astronomy.

## Appeal

You might be asking, "Why would anyone collect *old* books?" It's a good question, because antique books contain out-of-date information, usually are poorly illustrated, and can be hard to find.

Astronomy book collectors cite several reasons they're drawn to such works. First, there's the thrill of the hunt. I suppose this is true for any collector of obscure items. You must enjoy searching for books, visiting bookstores, and getting book catalogs in the mail. A challenge exists — find a few classics and build your collection from there.

In many cases, old books contain reports, ideas, or data that appeared for the first time in public. Members of small astronomy organizations (such as Britain's Royal Astronomical Society) may have attended a presentation or read a short report about the information, but even those individuals would have anticipated eagerly the full, written report.

Finally, the writing style makes old astronomy books fun to read. They're inviting, engaging, and poetic. Sometimes, descriptions venture into areas that, today, would be edited out for brevity:

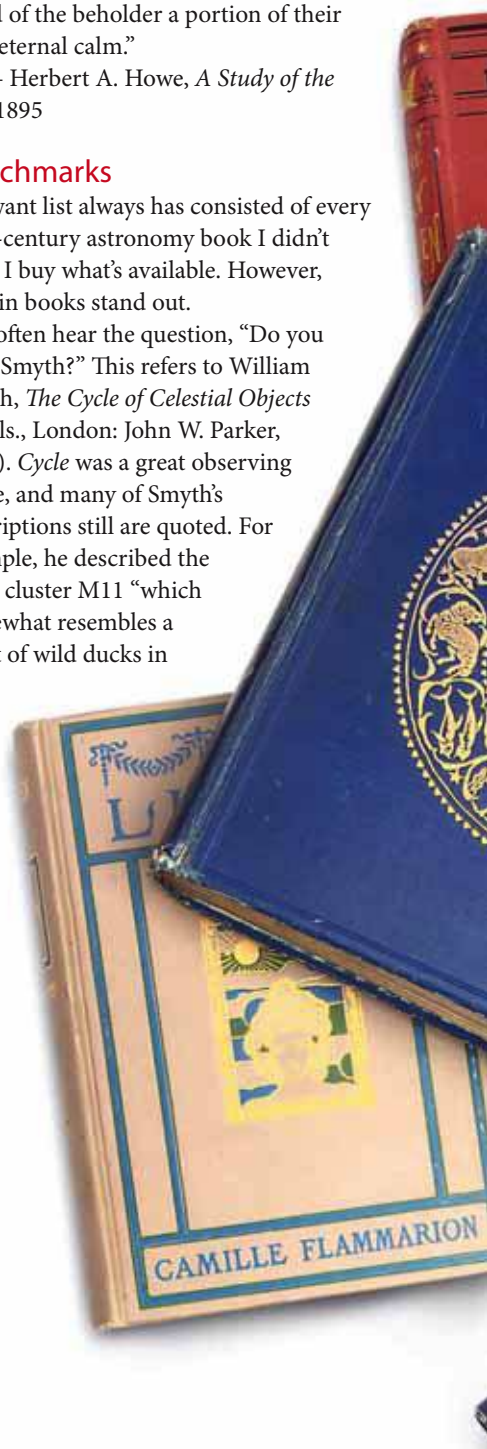
"Not in the garish glory of the day, when men's eyes are well-nigh blinded by the affluence of light which the Sun pours forth, and their minds are caged in the narrow round of daily toil, are the wonders of the sky revealed. But when the clangor and roar of the world's traffic have died away, and the last glint of the retiring Sun has vanished from the mountain top; when the soft shades of the evening twilight gradually melt into the darkness of the night, and the blessed shadow of the Earth steals over the abodes of men, bringing rest and refreshment of mind, then come forth the troops of radiant orbs, filling the sky with their splendid array, and giving to the mind of the beholder a portion of their own eternal calm."

— Herbert A. Howe, *A Study of the Sky*, 1895

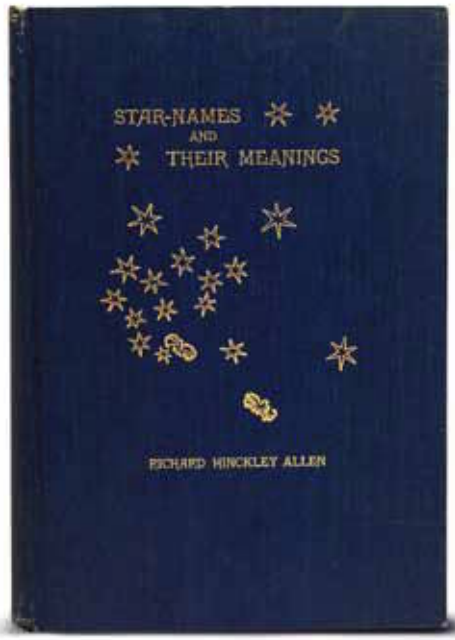
## Benchmarks

My want list always has consisted of every 19th-century astronomy book I didn't own. I buy what's available. However, certain books stand out.

I often hear the question, "Do you have Smyth?" This refers to William Smyth, *The Cycle of Celestial Objects* (2 vols., London: John W. Parker, 1844). *Cycle* was a great observing guide, and many of Smyth's descriptions still are quoted. For example, he described the open cluster M11 "which somewhat resembles a flight of wild ducks in



**A TRUE CLASSIC,** Allen's 1899 work *Star-Names and Their Meanings* set the standard for future stellar nomenclature studies. The Dover Publications edition of this book has been in print since 1963.




ALL PHOTOS: *ASTRONOMY*: JAMES FORBES

**NO COLORFUL DUST JACKETS** adorned books published a century ago, so publishers had to make the covers as appealing as possible.

## /// A UNIQUE COLLECTION

### PREFERENCES

I collect first editions because I'm interested in authors' earliest ideas. I also find it more of a challenge to acquire a title's oldest edition.

You don't have to concentrate on first editions, however, to have a valuable collection. I know a bibliophile who collects only the *last* editions astronomical writers completed in their lifetimes because such works demonstrate the culmination of the authors' thoughts.

What you collect is a personal choice. Let me pass on to you what a friend once told me: Identify your passion and pursue it. — *M. E. B.*

### SUB-COLLECTIONS

Most collections are made up of smaller collections, or categories, and astronomy books are no exception. A few categories related to observing include star atlases, observatory publications, and eclipse expedition write-ups.

My favorite sub-collection includes astronomy books written by 19th-century women. Women astronomers and science writers of this period were pioneers, and titles by them are uncommon. — *M. E. B.*

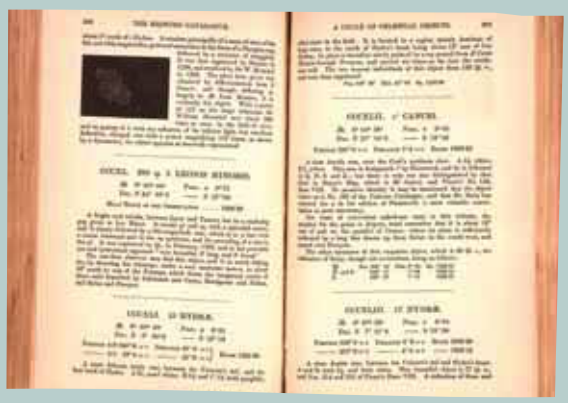
### THE QUESTION

When I show friends my collection, one question frequently is asked: "Which book is the most valuable?" Usually, I'm not sure what they mean by "valuable." Is it the monetary value, the personal value to me, or the popularity on today's bookseller's market?

In monetary value, John Herschel's *Results of Astronomical Observations . . . Cape of Good Hope* tops the list. However, the book I have that most collectors would like to own is *The Cycle of Celestial Objects* by William Smyth. The most popular one — without a doubt — is Percival Lowell's *Mars*.

If I rephrase the question as, "Which book is most special to me?" It's Mary Somerville's *Mechanism of the Heavens*. See "Build an astro library" in the December 2003 *Astronomy* for the reason for this choice. — *M. E. B.*

**ONE VOLUME WASN'T ENOUGH** for William H. Smyth to describe the sky in *The Cycle of Celestial Objects* (1844). Volume 1 provided an introduction, and Volume 2 gave each object's details.



**THE GREAT OBSERVING GUIDE** of the 19th century was William H. Smyth's first edition of *The Cycle of Celestial Objects*, which appeared in 1844. Smyth described stars, clusters, and nebulae (galaxies weren't understood yet) in the order in which they appeared in the sky. The illustration shows the star cluster M67 in Cancer.

**TRANSIT TELESCOPES** move up and down only. They helped astronomers record when a star passed due south. Smyth's 1860 edition of *The Cycle of Celestial Objects* illustrates an observer making timings. (Note the dark lantern illuminating the clock.)

## /// NEW CLASSICS

Perhaps you're interested in antique astronomy books but don't have enough time or money to purchase first editions. Don't despair. Many once-popular antique astronomy books have been reprinted in low-cost, softbound form. These books have the advantage of whiter paper than the originals, which makes the text easier to read. Some historical information often is included in the reprint's preface.

**ORIGINAL ANTIQUE BOOKS** may be hard to find. Some of the better known works have been reprinted. William Tyler Olcott's *Star Lore* is a collection of constellation myths first printed in 1911. *Star Names: Their Lore and Meaning* by Richard Hinckley Allen is a bit older. It first appeared in 1899. Both of these fine reference books are available from Dover Publications (*www.doverpublications.com*).

shape." M11 is still known as the Wild Duck Cluster.

*The Geography of the Heavens* by Elijah Hinsdale Burritt (Hartford: F. J. Huntington, 1833) made a splash. With the *Atlas Designed to Illustrate the Geography of the Heavens*, this pair was the 19th century's most popular astronomy teaching tool.

More than 300,000 copies of the charts were produced in 16 separate editions. I have the first edition of the text, and the second (1835) edition of the star maps. Once, years ago, I looked over the first edition maps, but they had been burned badly in a fire, and the book dealer still wanted $125. Even I have limits.

A title that will be familiar to many of you is the *New General Catalogue* (NGC) by John Louis Emil Dreyer (London: Royal Astronomical Society, 1888). This comprises the *Memoirs of the R.A.S.*, vol. XLIX, Part 1. My copy is bound together with Dreyer's *First Index Catalogue* (1895) and his *Second Index Catalogue* (1908).

It's funny how I've acquired some books. In 1988, a friend stopped by, pulled a book off my shelf, and replaced it with Dreyer. "We've just made a trade," he declared. I started to protest, until I saw the title, and the fine 19th-century raised-rib leather binding. Every observer owns a copy of the NGC. Only a few of us have first editions bound in leather.

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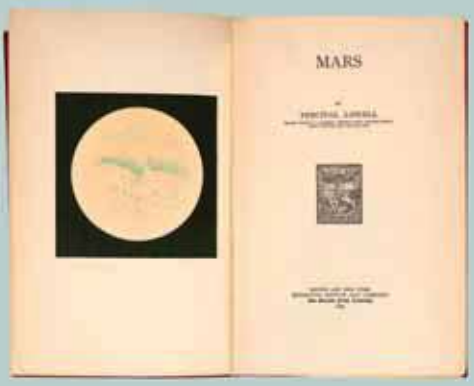
**Michael E. Bakich** *is an associate editor of* Astronomy *who loves old books.*

One of the rarest books in my collection is *Results of Astronomical Observations Made During the Years 1834, 5, 6, 7, 8 at the Cape of Good Hope* by Sir John Herschel (London: Smith, Elder & Co., 1847). This was Herschel's magnum opus. The book contains observations of southern double stars and nebulae, studies of the Magellanic Clouds, and descriptions and drawings of the Halley's Comet 1835 appearance. Five years of study under South Africa's southern sky were apparently enough because Herschel never resumed serious observing after returning to London.

One of my favorite finds is Percival Lowell's *Mars* (Boston & NY: Houghton, Mifflin & Co., 1895). The first printing of the first edition is not an easy book to find. I've seen only two.

When I first started collecting, I set a goal to acquire *Mars*. It took me 16 years of active searching, and it was like the best present you could imagine when the package arrived.

First appearances of ideas in antique books also are important. *A Selection of Photographs of Stars, Star-Clusters and Nebulae* by English amateur astronomer Isaac Roberts (London: The Universal Press, 1893) has an example. This work — a collection of images made at Roberts' private observatory — was the first true collection of astrophotos. Examining his Andromeda Galaxy (M31) photograph, Roberts was first to identify spiral structure in that object correctly.




**A FAMOUS 19TH-CENTURY BOOK** is Lowell's *Mars*, published in 1895. It described a civilization that once existed on the Red Planet and had astronomers refuting its conclusions until 1965, when Mariner 4 flew by Mars and put Lowell's wacky theories to rest.

**THE FIRST PRINTED COLLECTION** of astrophotos appeared in 1893 as *A Selection of Photographs of Stars, Star-Clusters and Nebulae* by Isaac Roberts. This 1887 photograph of the Andromeda Galaxy (M31) was the first to depict M31's spiral arms.

**ILLUSTRATIONS** a century ago were less valuable than text, but some books have a lot. Ball's *Atlas of Astronomy* (1888) contains detailed images, including this page showing an eclipsed Sun, a large sunspot group, and a colored illustration of prominences.

## Lesser-known important works

The benchmarks listed above are difficult to find and expensive, so obtaining one is a cause for celebration. Any number of books, however, could fit into the category "important but not recognized." If the book is important to you, it's worth acquiring.

Recently, I bought a book unfamiliar to me: Richard Phillips' *The Wonders of the Telescope* (London: Marchant, 1805). According to astronomy book dealer Paul W. Luther, who researched this work, it is "an observer's guide including images, comments and advice about the telescopic observation of the planets and stars. It also contains illustrations of two commercially available telescopes. Phillips claims in the title that this is 'On a Plan Never Before Attempted.' Although some might claim the first telescopic observer's guide was Galileo's *Siderius Nuncius*, I think a good case can be made that this book, clearly intended for 'amateur' astronomers, is the first example of what we would now call an observer's guide."

After only 27 years of collecting, I should know better than to think I have a grasp on all 19th-century astronomy books. There continue to be surprises. The acquisition of Phillips' book was one of those instances where I was happy to acknowledge my ignorance.

## Discoveries await

My research tells me that 1,200 to 1,500 books exist in my "realm." Realistically, I'll never own them all. My current library accounts for 416 first editions.

If you begin collecting antique astronomy books, chances are you'll find items I've never seen. You also will set different goals than mine. I still have a few benchmarks to acquire, let alone lots of the lesser-known books.

In 1990, I announced to a small circle of collectors a lifetime goal of 500 books. I made no distinction regarding subject matter, condition, or perceived rarity. You may choose to collect books that cover specific topics, such as the Moon, or you may focus on particular authors.

Whether you choose books by 19th-century observers or books about them, you'll meet dedicated — sometimes obsessed — astronomers that will become lifelong friends. Say "hi" to Percival Lowell for me.

**BOOKS ABOUT THE 19TH CENTURY** are easier to find than books written during that time period. If you find yourself drawn into the 19th century, check out these current books to read about what made astronomy exciting back then. Biographies are popular, including *Lowell and Mars* (1996, fourth from left). Other popular topics are highlights of 19th-century astronomers (*The Victorian Amateur Astronomer*, 1999, third from left) and historical accounts (*Centennial History of the ... Mount Wilson Observatory*, 2005, fifth from right).

**ONLINE EXTRA** Discover more great books at www.astronomy.com/toc

Nebula filters cut sky glow and let you see more with less.

/// BY PHIL HARRINGTON

ALL FILTER IMAGES *ASTRONOMY*: WILLIAM ZUBACK

# Secret weapons

## It seems inevitable. No sooner do you get a new telescope than you begin to wonder what to buy next. Maybe some filters? Sounds like a good idea, but which ones? Amateurs use many different filters, but the most intriguing — and least understood — are light-pollution reduction (LPR) filters and nebula filters.

### How filters work

Can we actually filter out light pollution? Yes, because many outdoor lighting sources do not shine evenly across the visible spectrum. Instead, they emit radiation at only a few distinct wavelengths. For instance, the common high-pressure sodium-vapor streetlight used throughout North America radiates principally in yellow wavelengths. Mercury-vapor lamps radiate green and blue wavelengths. LPR filters suppress those light wavelengths, while allowing others through.

"Nebula filters" have a different mission. They are designed for the sole purpose of observing emission and planetary nebulae. Fluorescence causes ionized atoms in these objects to glow.

Because these nebulae are composed largely of hydrogen, most of their visible-light emissions occur in the far-red and blue ends of the visible spectrum, but they emit greenish light from doubly ionized oxygen as well.

Most nebula filters muffle all wavelengths except those associated with ionized hydrogen and doubly ionized oxygen. Because they block all but a small part of the spectrum, these filters are more correctly called "narrow-band filters."

Other nebula filters suppress all visible light except for a specific wavelength, or line, that they allow to pass through. "Line filters" come in two varieties: Oxygen III (abbreviated OIII) and Hydrogen-beta (Hβ). As we will see, some narrowband and line filters are more appropriate for certain objects than others.

All three filter types are made essentially the same way: Within a vacuum chamber, a machine deposits precise, ultra-thin layers of inorganic coatings with known optical characteristics on thin glass blanks. When certain light wavelengths strike specific layers, the layers reflect the light rather than passing it through.

### Setting the record straight

There are misconceptions about these filters. Some people mistakenly believe LPR filters reduce all forms of light pollution. This seems like a natural assumption given the filter's name, but it's just not the case.

LPR filters block certain wavelengths, but they do little to reduce the impact of car headlights, lights directed onto buildings, and other fixtures using incandescent bulbs, which (unfortunately for the astronomer) shine at all visible wavelengths.

Rather than the term "light-pollution reduction filter," it would be better to use their proper name: "broad-band filter." That's because they filter out a wide range of wavelengths. Similarly, nebula filters should be referred to as either "narrowband" or "line" filters.

Another common fallacy is that these filters make deep-sky objects look brighter. Not so. Filters decrease all light at all wavelengths, but they transmit more of the desireable wavelengths. As a result, the background sky and field stars darken more than the target. This boosts the contrast, making objects easier to spot.

NEBULA IMAGE: JASON WARE

## /// HOW FILTERS WORK ON SELECTED OBJECTS

| Company | Type | B33 | NGC 2371-2 | M76 | NGC 1514 | M42 | M1 | M37 | M81 |
|---|---|---|---|---|---|---|---|---|---|
| | No filter | 0 | 2 | 3 | 0 | 3 | 3 | 4 | 3 |
| **Astronomik** | | | | | | | | | |
| CLS | B | 0 | 2 | 4 | 1 | 3 | 2 | 5 | 4 |
| UHC | N | 0 | 3 | 4 | 2 | 5 | 4 | 3 | 2 |
| O-III | O | 1 | 3 | 4 | 3 | 5 | 4 | 3 | 2 |
| H-Beta | H | 2 | 1 | 1 | 1 | 4 | 2 | 2 | 1 |
| **Baader** | | | | | | | | | |
| UHC-S | N | 0 | 3 | 4 | 1 | 4 | 4 | 3 | 2 |
| OIII | O | 1 | 3 | 5 | 3 | 4 | 4 | 3 | 2 |
| Neodymium | B | 0 | 2 | 3 | 2 | 3 | 3 | 4 | 3 |
| **Celestron** | | | | | | | | | |
| UHC-LPR | N | 0 | 3 | 4 | 1 | 4 | 4 | 3 | 2 |
| **DGM Optics** | | | | | | | | | |
| VHT | B | 0 | 2 | 4 | 1 | 4 | 4 | 4 | 3 |
| NPB | N | 1 | 4 | 5 | 3 | 5 | 5 | 3 | 2 |
| **IDAS** | | | | | | | | | |
| LPS-P | B | 0 | 2 | 3 | 1 | 3 | 3 | 3 | 3 |
| **Lumicon** | | | | | | | | | |
| Deep Sky | B | 0 | 2 | 3 | 1 | 3 | 3 | 4 | 4 |
| UHC | N | 0 | 3 | 4 | 3 | 5 | 3 | 3 | 2 |
| O-III | O | 0 | 4 | 5 | 2 | 5 | 4 | 2 | 2 |
| H-Beta | H | 2 | 1 | 1 | 0 | 5 | 1 | 1 | 1 |
| **Meade** | | | | | | | | | |
| 908B | B | 0 | 3 | 3 | 2 | 3 | 3 | 4 | 4 |
| 908N | N | 0 | 3 | 4 | 3 | 4 | 4 | 3 | 2 |
| 908X | O | 0 | 4 | 5 | 3 | 5 | 4 | 3 | 2 |
| **Orion** | | | | | | | | | |
| SkyGlow | B | 0 | 2 | 3 | 2 | 4 | 4 | 4 | 4 |
| UltraBlock | N | 0 | 4 | 4 | 3 | 5 | 4 | 2 | 2 |
| **Tele Vue** | | | | | | | | | |
| Nebustar | N | 0 | 3 | 4 | 3 | 4 | 5 | 3 | 2 |
| O-III | O | 0 | 4 | 5 | 3 | 5 | 4 | 2 | 2 |
| **Thousand Oaks** | | | | | | | | | |
| LP-1 | B | 0 | 2 | 3 | 1 | 4 | 4 | 4 | 4 |
| LP-2 | N | 0 | 3 | 4 | 2 | 4 | 3 | 3 | 2 |
| LP-3 | O | 0 | 4 | 5 | 3 | 5 | 4 | 3 | 1 |
| LP-4 | H | 2 | 1 | 1 | 0 | 4 | 2 | 1 | 1 |

I rated the view of each object on a 0–5 scale adapted from my book *Star Watch* as follows: 0 — object invisible; 1 — visible only with great difficulty; 2 — visible with moderate difficulty; 3 — visible with little difficulty; 4 — visible easily; and 5 — wow!
B = Broadband; H = Hβ ; N = Narrowband; O = OIII

Some amateurs believe these filters dim the view so much they can't be used with small telescopes. That's not true. Any telescope can benefit from these filters. I even have used identical filters taped to the eyepieces of binoculars to detect faint celestial objects that were invisible otherwise.

Finally, there's the myth that filters are only for urban and suburban observing — that they're not needed for observing out in the country. Although broadband filters make their biggest impact under severe light pollution, narrowband and line filters enhance the view of emission and planetary nebulae no matter where you are.

## Testing

To find out just how well today's most popular filters perform, I gathered more than two dozen broadband, narrowband, and line filters. Although many manufacturers make both 1¼" and 2" sizes, I restricted my tests to 1¼" models only to include all manufacturers.

A visual examination showed all the filters were made to high optical standards. Coatings appeared uniform, and the machined metal housings were either anodized or painted. Each was labeled for easy identification under dim lighting, and each screwed into my threaded eyepiece barrels smoothly. Most were black, which could make them difficult to find at night if misplaced. Only the four Thousand Oaks filters were anodized with different colors.

The winter constellations were riding high during these tests, which gave me a great choice of deep-sky objects to observe. All observing sessions were conducted from my light-polluted backyard, where I typically can see magnitude 5 stars with my naked eyes. Sky glow is severe in some directions, but I still get a good view overhead. These conditions let me see how well the filters work against moderate light pollution.

I tried each filter on showpiece objects like the Orion Nebula (M42) and the Crab Nebula (M1), as well as on some difficult targets, including the Horsehead Nebula (B33). I also checked several planetary nebulae as well as a few open clusters and galaxies.

To judge how well the filters performed, I laid them on a table, mixing up their order so I couldn't recognize one from another during the test. Only after I observed an object through a filter did I turn on a red light to identify the filter and write down my results.

## Filtering through the results

Not surprisingly, the broadband filters did best against objects such as star clusters and galaxies, which radiate a wide range of wavelengths. While a filter seldom showed more detail than an unfiltered view or revealed an otherwise invisible target, broadband filters improved the visual aesthetics by darkening the background.

Of the seven broadband filters I tested, the Orion SkyGlow delivered the best results. It added just enough contrast to make an object stand out nicely without sacrificing too much image brightness. I also judged the DGM Optics Very High Throughput (VHT), Meade 908B, and Thousand Oaks LP-1 filters effective. Images remained bright and clear through all three test telescopes: my 4-inch refractor, and 8- and 18-inch reflectors.

The VHT did better on nebulae, while the others were better on star clusters and galaxies. Rounding out the pack were the Astronomik CLS, followed by the Baader Neodymium and Lumicon Deep Sky filters in a tie, and finally the IDAS LPS-P.

Of the nine narrowband filters, I judged DGM Optics' Narrow Pass Band (NPB) filter the best on emission and planetary nebulae. What sold me were the views I had of the Crab Nebula, the Little Dumbbell (M76), NGC 1514, and especially M42.

**Phil Harrington** *is the author of the observing guidebook* Star Watch*, published by John Wiley & Sons.*

The faint tendrils of M42 looked as though they were stretching outward like fingers grasping at nearby stars. I also was impressed with the images delivered by Orion's UltraBlock and Tele Vue's Nebustar Bandmate filters.

Views through Meade's 908N, Lumicon's UHC, and the Astronomik UHC filters also were pleasing although not quite as contrasty as the others. Readers looking for a narrowband filter would be satisfied with any of these. I found the Baader UHC-S, the Celestron UHC-LPR, and Thousand Oaks LP-2 less effective, however.

Results were exceptionally close in the OIII round of testing. I wasn't disappointed with any contender, but found the views through the Meade 908X were the best. I enjoyed the details revealed in M42, as well as some otherwise invisible features in several planetary nebulae. Likewise, the Astronomik, Baader, Tele Vue, and Thousand Oaks filters each showed some subtleties in objects that eluded detection in the other filters, save for the 908X (and, in some cases, the DGM NPB). The Lumicon filter darkened the field of view more than the rest.

Finally, I tested three Hβ filters. They produce positive results with only a handful of emission nebulae. Here, the Astronomik Hβ filter rose above the others, but only by the narrowest measure. Through my 18-inch reflector, all three Hβ filters revealed the dim silhouette of the Horsehead Nebula against the subtle backdrop glow of IC 434 when there wasn't a hint of this object through the others. All three also showed finer structure in M43 — the tiny appendage hanging off the northern edge of the Orion Nebula — than any of the OIII or narrowband filters, and even added new dimensions to M42 itself.

All tested filters increased contrast between deep-sky objects and the background sky. If you live under a dome of light pollution, consider adding a broadband filter to your equipment arsenal. If you enjoy searching for tough planetaries or challenging emission nebulae, then either a narrowband or OIII filter is a must-have. For us deep-sky diehards who already own the others, an Hβ filter will prove handy, even though it likely will see less starlight than other filters.

Once you start using filters, you'll be amazed at what you've been missing. It's the same pleasant experience as putting on your "shades" on a sunny day.

## /// CONTACT INFORMATION

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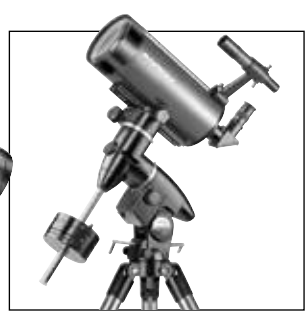

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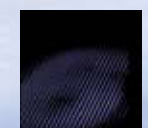

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Recreation and Environmental Center, the Connecticut River Valley Astronomers Conjunction has called skygazers to north-central Massachusetts for more than 2 decades. The weekend provides East Coast astronomers with an escape from the vast light pollution of metropolitan regions.

JERRY SCHAD

**THE PERSEID METEOR SHOWER, falling this year just before a First Quarter Moon, should be strong and will be the main attraction at many mid-August star parties.**

In addition to observing, the star party will feature talks by leading figures representing the science and hobby of astronomy, such as *Astronomy* contributing editor Phil Harrington. Lectures will cover topics from energy in the universe to making a backyard observatory.

As with past Conjunctions, the Saturday roundtable is the weekend's highlight. This year's topic is "Your favorite astro-accessories." Bring your best eyepiece, CCD device, or observing chair to this show-and-tell and share it with the group.

For more information, visit this site: www.philharrington.net/astroconjunction.

AUGUST 4–7
### Saskatchewan Summer Star Party
Cypress Hills Interprovincial Park, near Maple Creek, Saskatchewan. The high-altitude park is now a dark-sky preserve, so terrific observing is guaranteed. For more information, visit www.usask.ca/psychology/sarty/rasc.

AUGUST 4–7
### Starfest
The River Place, near Mount Forest, Ontario. The largest star party in Canada, this year's gathering will feature observing, workshops, and lectures by prominent astronomers. For more information, visit www.nyaa-starfest.com.

AUGUST 4–6
### Table Mountain Star Party
Table Mountain, near Ellensburg, Washington. This is the 25th annual gathering on Table Mountain. Star-party attendance is restricted to 700 people, so register as soon as possible. For more information, visit www.tmspa.com.

AUGUST 4–6
### Weekend Under the Stars
Near Foxpark, Wyoming. This star party will feature lectures, vendors, workshops, prizes, and excellent observing. Under a dark sky at 9,100 feet (2,800 meters), some 7th-magnitude stars can be seen with the naked eye. For more information, visit home.bresnan.net/~curranm.

AUGUST 5–6
### Northwoods Starfest
Beaver Creek Reserve, near Eau Claire, Wisconsin. This is the 16th annual gathering at Hobbs Observatory. A 5-meter dish at the observatory will be of interest for fans of radio astronomy. For more information, visit www.cvastro.org.

AUGUST 5–6
### Stellafane
Springfield, Vermont. Hosted by the Springfield Telescope Makers, this event is the largest and oldest gathering of amateur telescope-makers in the world. *Astronomy* Senior Editor Rich Talcott will attend. For more information, visit www.stellafane.com.

AUGUST 10–14
### Great Manitou Star Party
Aundeck Omni Kaning, near Little Current, Manitoulin Island, Ontario. Guests on the island will be treated to an eclectic mix of music, indigenous culture, and astronomy. For more information, visit, manitoulindarksky.com.

AUGUST 10–14
### ALCON
Kansas City, Missouri. There will be an astronomical trade show, vendor exposition, speakers, and observing at Powell Observatory. *Astronomy* Associate Editor Michael E. Bakich will attend. For more information, visit www.astroleague.org.

AUGUST 10–14
### Medomak Perseid Star Party
Medomak Retreat Center, Washington, Maine. This dark-site retreat will reveal many targets beyond the Perseids. For more information, visit www.medomakcamp.com.

AUGUST 13
### Wayne County Astronomical Society Star Party
Wooster Memorial Park, Wooster, Ohio. This gathering will feature day and nighttime observing. For more information, visit www.wacas.org.

AUGUST 20
### Harvest Moon
Jeffers Petroglyphs Historic Site, Comfrey, Minnesota. In addition to observing the Full Moon, visitors will learn about the Moon through hands-on activities and stories from various cultures. For more information, visit www.jefferspetroglyphs.com.

AUGUST 27
### AANC-Con and John Dobson Birthday Celebration
Josephine Randall Museum, San Francisco. Join California skygazers for astronomy legend John Dobson's 90th birthday. The party will feature speakers and a Dobsonian telescope project. For more information, visit www.aanc-astronomy.org.

SEPTEMBER 1–5
### ICStars Star Party
ICStars Ranch, Warrensburg, Missouri. Extended through Monday, September 5, because of the Labor Day weekend, this event will feature many activities for children, including hayrides, a fossil hunt, and a planet-making workshop. For more information, visit icstars.com/index.html.

SEPTEMBER 1–4
### Iowa Star Party
Garst Farm Resort, Coon Rapids, Iowa. Attendees can choose among accommodations ranging from tents to suites in the bed-and-breakfast. For more information, visit www.iowastarparty.com.

CONTACT INFORMATION
Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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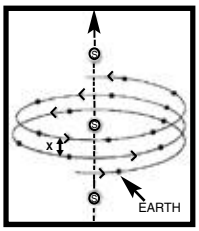

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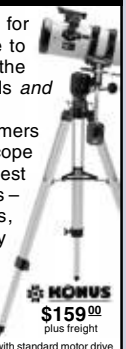


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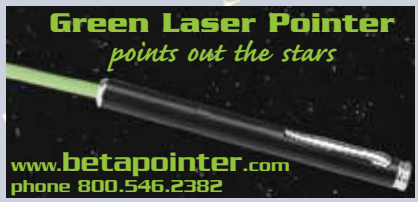


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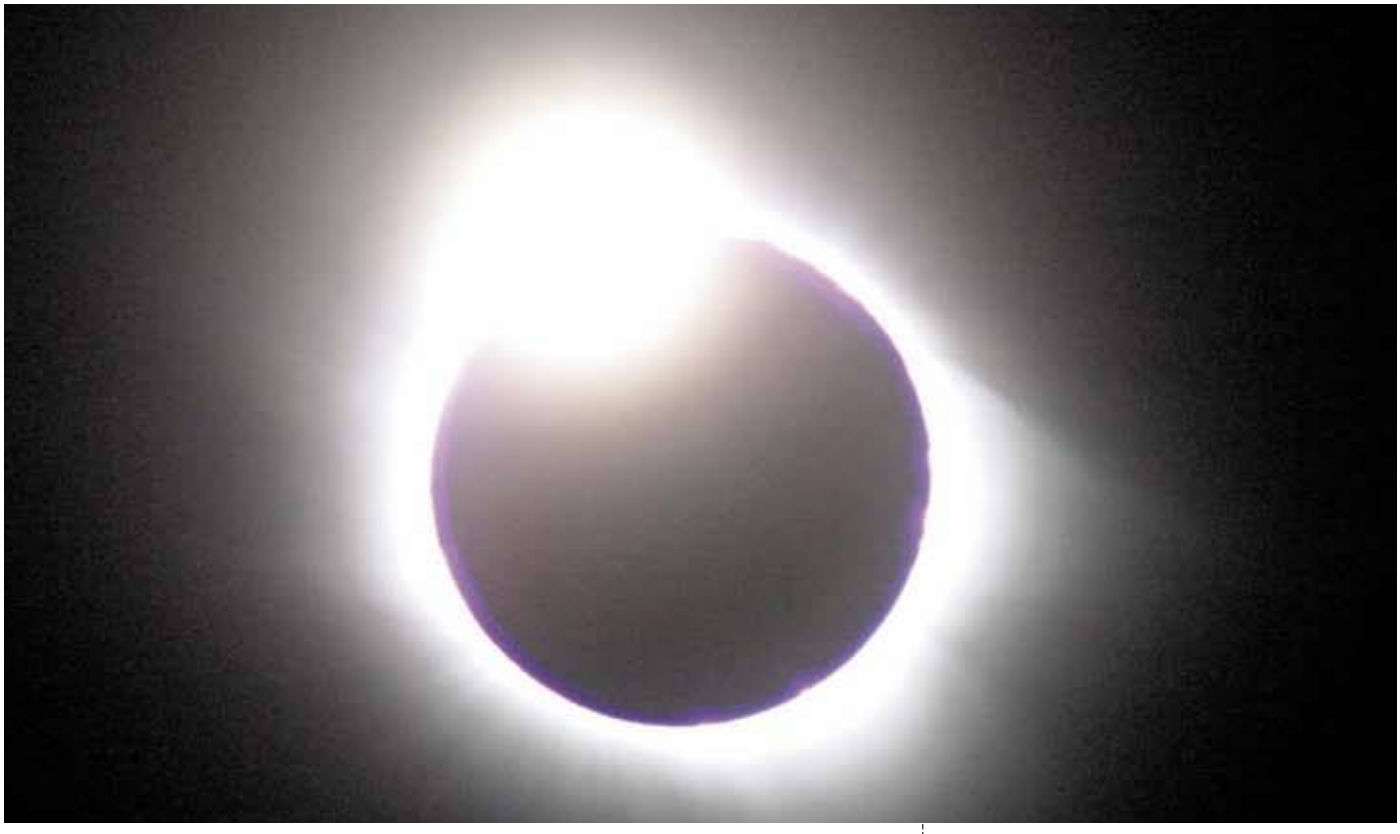
# Reader gallery

## Readers share their images...

April 8, 2005, total solar eclipse /// Diamond ring /// Venus near the Sun
Red chromosphere /// Clouds before totality /// Old "pre-eclipse" Moon /// Partial phase



**DIAMOND RING AND CORONA** (3.2-inch Megrez 80II semi-apochromatic refractor at f/6.25, Canon EOS 10D digital SLR, 1/500-second exposure at ISO 400) /// **MIKE REYNOLDS ABOARD THE M/S *PAUL GAUGUIN* NORTH OF PITCAIRN ISLAND**

**PACIFIC DARKNESS**

## Total solar eclipse April 8, 2005

**It's been called the greatest of nature's spectacles — a total eclipse of the Sun. For the lucky individuals who have seen one, nothing else comes close. A partial solar eclipse — whatever percentage of the Sun is covered — doesn't approach totality's beauty. South Pacific travelers took the following pictures aboard two *Astronomy*-sponsored ships that cruised under the Moon's shadow April 8. Your next chance to see a total solar eclipse occurs March 29, 2006. *Astronomy* editors will escort groups on a land tour of Turkey and a Mediterranean cruise to observe the event. Find out more about these trips at www.astronomy.com.**

**DURING TOTALITY, VENUS** appeared 2° east of the Sun. Its brilliant, starlike appearance contrasted nicely with the silvery solar corona. Because this eclipse was short, the sky never got dark enough for observers to see other celestial objects. (Nikon D100 digital SLR, 200mm lens at f/2.8, 1/125-second exposure) /// **JEAN-LUC DIGHAYE ABOARD THE M/S *PAUL GAUGUIN* NORTH OF PITCAIRN ISLAND**

**RED WAS THE COLOR**

///

**CLOUDS BEFORE TOTALITY**

///

DURING A SOLAR ECLIPSE,

///

**AS THE ECLIPSE ENDED** and the Sun's disk slowly reappeared, the second brilliant diamond ring became visible. One traveler playfully described the ring's appearance as, "First it was 1 carat, then 2, then 4."

///

BEFORE AND AFTER TOTALITY,

///

INTERNAL REFLECTIONS

///

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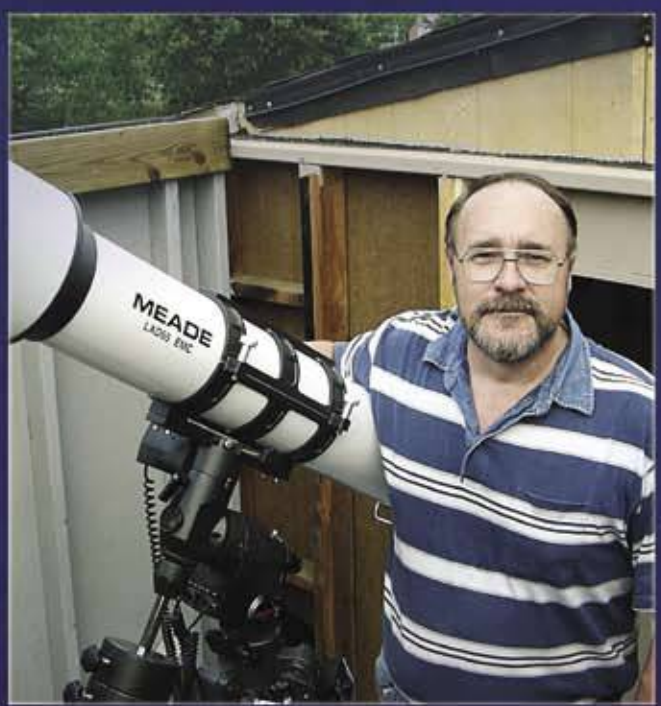
## "I've already used the DSI more than any eyepiece in my collection."

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George Lilley

– George Lilley
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